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Weeds/weed seedbank and soil fungi responses to tillage and cropping systems

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Weeds/weed seedbank and soil fungi responses to tillage and cropping systems

by

Joel Felix

A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Crop Production and Physiology

Major Professors: Micheal D. K. Owen and Thomas E. Loynachan

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For the Graduate College

DEDICATION

To my mother, my greatest teacher, Yuliana F. Lugeiyamu. This is also dedicated to my wife Elizabeth N. Felix, my kids, Beatrice B. Lugeiyamu, Felix R. Lugeiyamu, and Oliver M. Lugeiyamu for their love and support throughout the years. To Alice K. Rwehumbiza who introduced me to Agricultural Research. You are all great.

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ABSTRACT

A four year field experiment was conducted from 1994 through 1997 to elucidate the effect of tillage, cropping systems, and weed management regimes on land previously under the conservation reserve program (CRP). A total of thirteen weed species comprised the weed seedbank which was dominated by broadleaf weeds. The seedbanks for common lambsquarters and pigweed species were 10,365 and 31,925 seeds m^{-2} in the first year out of CRP, respectively. The pigweed seedbank increased with time and climaxed at 51,670 seeds m^{-2} in 1996. The seedbank for *Setaria* species increased 19 fold between 1994 and 1997. Tillage and cropping systems did not influence weed population or seedbank throughout the duration of the study. Weed management had the greatest influence on weed population changes, with no herbicide treatment having a higher weed and weed seedbanks compared to band and broadcast treatments which had a similar effect. Continuously cropped fields in Iowa had a larger weed seedbank compared to that in adjacent CRP fields. The common lambsquarters, *Amaranthus* species, and *Setaria* species weed seedbanks differed significantly in the nine Iowa crop yield reporting districts. The land coming out of CRP is likely to have a larger broadleaf seedbank and fewer grasses. Soil phosphorus levels were higher in no till system compared to conventional tillage. The resident soil fungus population was dominated by Fungi Imperfecti with 38 species in 18 genera. *Trichoderma* and *Penicillium* species had the highest population densities. Generally, no herbicide plots had higher fungal population densities per gram of soil compared to band and broadcast treatments. Three genera of Zygomycetes and two species in one genus of Ascomycetes were identified.

CHAPTER 1. GENERAL INTRODUCTION

Two of the major issues facing sustainable agriculture are soil erosion and pesticide use. Soil erosion causes more environmental damage and economic loss than any other issue facing agriculture today. Similarly, when pesticide use is characterized by the public, herbicides are suggested to represent the primary environmental concern. However, when economics are considered, weeds are the most important management issue for agriculture. The primary reason for tillage and herbicide use is the efficient maintenance of weeds to a tolerable level in a crop field. Economics and "tradition" seemingly have enforced the need for crop production systems that emphasize yields without due consideration to environmental concerns. Thus, there is a direct conflict between most current crop management systems and sustainable agriculture.

Recent concern for the environment and a changing economic perspective have placed a considerable burden on the agricultural community. As a result, crop production systems that optimize yields while conserving soil and reducing ground and surface water contamination by pesticides have received much publicity. Current interest in no tillage (NT) crop production is a direct result of these concerns. However, most practitioners of conservation tillage systems feel that weed management is a serious problem which often results in increased herbicide use.

Another important factor in soil erosion is the conservation reserve program (CRP) that was enacted as part of the 1985 Food Security Act (USDA 1992). This was established as a voluntary program to help agriculture prevent soil erosion on more than one-third of crop acres in the USA (USDA 1986). Most of the crop land in capability classes VI, VII, and VIII

result in excessive erosion in relation to the soil loss tolerance level ("T") and thus qualified for the program. Nationally, approximately 750,000,000 tons of soil have been conserved as a result of CRP, representing an annual $2 billion savings in off-farm clearing of eroded soil.

Other important benefits of CRP are wildlife enhancement, improved water quality by reducing sedimentation to streams and surface water by approximately 211 million tons annually, and income support to participants. The CRP was a 10-yr program that expired following the enactment of the 1997 farm bill. A large portion of the land coming out of CRP will be returned to row crop production starting in September 1997. Growers were required to utilize tillage systems that will not cause considerable erosion if gains in CRP were to accrue. The primary factor governing CRP conversion systems is control of the cover species (Medlin et al. 1998). Therefore, research on land coming out of CRP was imperative if we were to correctly advise the producers on how to best return land to row crop production without causing further soil erosion.

Dissertation Organization

The research is presented as four research papers: the first paper deals with weed population dynamics in land removed from the conservation reserve program (CRP). The second paper addresses the weed seedbank dynamics in post CRP land, while the third investigates the weed seedbank comparison between CRP land and adjacent continuously cultivated fields in Iowa. The fourth paper addresses the issues related to the effects of tillage, cropping systems, and weed management on soil fungal population densities in the land formerly under CRP. A general literature review precedes the first paper and a general

summary follows the fourth paper. A literature cited section is included at the end of each paper. Literature cited in the General Introduction is listed after the final chapter.

Literature Review

Predicting potential weed emergence is a fundamental need in the development of integrated pest management strategies for weed control (Cardina et al. 1996). If growers could predict the composition and density of weed seedlings that emerge during a growing season they could plan and implement appropriate control measures only when and where necessary (Cardina and Sparrow 1996; Sagar and Mortimer 1976).

When tillage systems are altered, an immediate change in the crop/weed relationship occurs (Forcella and Lindstrom 1988). This change is not fully understood and likely represents the major problem in the successful implementation of conservation tillage systems. Growers may abandon NT because of weed problems that occur due to a knowledge void about changes in weed ecology. Similarly, it is likely that growers who are successful practitioners of NT make inappropriate use of herbicides due to the same knowledge void. The research reported here investigated the ecological changes that occur in different cropping systems attributable to different tillage regimes.

Tillage and Weed Seedbank

Tillage systems influence weed seed germination rates and the level of control, thus affecting future weed populations. Shallow cultivation can induce weed seed germination and dilute the active seedbank by placing seeds in an environment that allow germination

(Wilson 1988), resulting in an overall reduction in the weed seedbank. However, the populations of many weeds may remain stable due to other mechanisms, such as dormancy and variable germination capabilities (Shaw and Hainero 1990). The ecology of weeds changes in response to the indigenous agricultural practices (Knab and Hurle 1986). Froud-Williams et al. (1983) suggested that perennial grass and broadleaf weeds increase when tillage is reduced. However, Buhler et al. (1993) suggested that perennial weed populations do not change dramatically regardless of tillage. Annual weed species do demonstrate significant differences in response to tillage systems (Kotile 1992).

Pollard and Cussans (1976) and Bachthaler (1974) reported that increased tillage resulted in more dicot weed seedlings compared to grasses. Froud-Williams et al. (1983) found that weed seed populations declined significantly in plowed locations compared to NT systems, although the percentage of decline varied by site. Annual grasses and small-seeded annual broadleaf weeds demonstrated higher populations under NT compared to complete tillage systems (Owen 1992).

Tillage also impacts the physical location of the weed seedbank. Wicks et al. (1971) reported that as the intensity and frequency of tillage declines, the weed seedbank move closer to the soil surface. Therefore, components of a weed management strategy that are optimized in a shallow soil environment likely will improve the effectiveness of reduced tillage cropping systems. Wilson (1988) reported that reduced tillage left 50% of the weed seeds in the upper 7-cm of the soil, as compared to more intensive tillage systems where weed seeds were evenly distributed throughout the upper 30-cm of the soil.

Pareja et al. (1985) found that in Iowa, soils under reduced tillage systems had an average of 24 seeds per 100 g soil, a 6 fold increase in weed seed populations found in conventional tillage (CT) systems. Burnside et al. (1986) reported that plowing reduced the total weed seed populations in the soil and that grass weeds were more affected than broadleaf weeds. However, it was suggested that growers should not reduce weed management strategies despite a significant decline in the weed seedbank as the remaining weed seed population was sufficient to rapidly replenish the weed population.

Schweizer et al. (1984) observed a decline in redroot pigweed *(Amaranthus retroflexus)* and *Chenopodium* spp. seeds of 34 and 22%, respectively, after one cropping year. However, the seedbank remained stable until the fourth cropping year. After the sixth year, the weed seeds had declined 99 and 91% for redroot pigweed and *Chenopodium* spp., respectively. Schweizer et al. (1984) concluded that intensive weed management should be employed for the first few years if a large weed seedbank exists, but that less intensive strategies could be successful after the weed seedbank declined. He cautioned, however, if the environment negatively impacted the weed management strategies, new weed seeds were introduced via wind, contaminated crop seed or irrigation water, or where weed resistance to herbicides develops, the weed seedbank will rapidly increase and intensive management strategies will be necessary.

Cropping History and Weed Seedbank

The composition and density of the soil weed seedbank vary greatly and is closely linked to the cropping history (Holt 1988). Kelly and Bruns (1975) compared the soil

seedbank of a grassland with adjacent soil subjected to 5 years of crop production. Seed population density was four times greater in the cropped land compared to the grassland. Barnyard grass *(Echinochloa crusgalli),* common lambsquarters (*Chenopodium album*), and pigweeds (*Amaranthus* spp.) comprised 90% of the weed seedbank in the cropland soils but were not present in the grassland soils.

Weed seedbanks in arable land may be quite large and are reported to range from 1,000 to 20,000 seeds m^{-2} (Kropac 1966) and as high as 496,000 seeds m^{-2} (Froud-Williams et al. 1983). Crop management and weed control programs are closely linked and influence changes in the soil weed seedbank (Wilson 1988). Roberts (1970) reported that the number of weed seeds in the soil could be maintained at 25,000,000 ha^{-1} or less when appropriate use of herbicides and tillage were employed in conjunction with crop rotation.

Forcella and Lindstrom (1988) reported that when continuous corn and corn/soybean rotations were used both under conventional and ridge tillage systems, 1,500 to 3,000 weed seeds m^{-2} (to a depth of 10 cm) were observed in continuous corn under ridge tillage. Weed seed production was approximately 66% less in CT corn. Soil from the corn/soybean rotation contained 200 to 700 weed seeds m^{-2} regardless of tillage. Crookston et al. (1981) reported that the soil seedbank for continuous corn production systems was twice as large as the soil seedbank for crop rotation production systems.

Weed Seedbank Survival in the Soil

The accepted advantages of NT crop production systems include reduced soil erosion, energy conservation, reduced soil compaction, reduced soil moisture evaporation, improved

water infiltration and less soil temperature fluctuation (Sen 1987). However, these advantages are also experienced by the weed population, and weeds are potentially placed in a superior competitive position to crop seeds in NT production systems (Froud-Williams et al. 1983). Thus, it becomes more critical to manage weeds in NT systems than in production systems that include tillage.

The fate of the soil weed seedbank reflects considerations of germination, dormancy, predation, and loss of viability; these factors are influenced by the physiological status of the seed and the environmental conditions of the soil (Schafer and Chilcote 1970). Weed seeds that remain in the soil for a period of years tend to associate with soil particles and get incorporated in soil structural units (Pareja et al. 1985). This association may occur regardless of tillage.

Weed seed germination is affected by moisture and oxygen levels in the immediate vicinity of the seed (Pareja and Staniforth 1985). The oxygen status of the soil-seed microsite is affected by the soil water content and soil porosity. Many weed seeds persist in the soil because the germination requirements are not met in the soil-seed microsite, and the seed remains dormant.

Further, weeds are very prolific seed producers, and a high percentage of these seeds are viable thus increasing the probabilities of survival in the seedbank (Holt 1988). It was estimated that 12 yrs were required to deplete the soil seedbank of viable velvetleaf *(Abutilon theophrasti)* seeds to 99% of the original level (Egley and Chandler 1983).

Roberts (1970) suggested that the rate of weed seed loss from the soil seedbank followed an exponential decay curve. However the rates of decay vary for different species

(Roberts and Feast 1972). Several factors affect the loss of seeds from the soil seedbank. These factors include seed germination, predation from vertebrates and invertebrates, and infection by soil microorganisms (Cavers and Benoit 1989).

There are a number of crop management factors that influence soil microorganism populations. Notably, higher levels of plant residue resulting in NT systems increased microbial populations in the topsoil compared to those in CT (Norstadt and McCalla 1969). Higher microbial population in the zone of weed seed germination enhances the depletion of the active seedbank through increased microbial infection of weed seeds (Pitty et al. 1987).

Kremer and Spencer (1989) reported that *Fusarium* spp., *Alternaria alternata* and *Cladosporium cladosporioides* were the most prevalent fungi associated with velvetleaf seeds in the soil. The incidence of *Fusarium* increased by 25% when velvetleaf seeds were attacked by the scentless plant bug *(Niesthrea lousianica)* in the field. Pitty et al. (1987) observed that the same fungi were associated with the deterioration of green foxtail *(Setaria viridis)* and giant foxtail *(Setaria faberi)* seeds in the soil. Also, the percentage of colonized weed seeds was higher in reduced tillage and colonized weed seeds were located shallower in the soil profile compared to those in conventional tillage. Under CT, greater seed colonization occurred deeper in the soil.

Chemical enhancement of fungal attack on weed seeds in the soil also has been reported. Kremer and Schulte (1989) reported that the number of hard seeds of velvetleaf decreased only when *Fusarium oxysporum* colonization of the seed was associated with the application of the herbicide butylate (S-ethyl bis(2-methylpropyl) carbomothioate). Kremer (1993) suggested that manipulation of the soil weed seedbank with microorganisms

associated with the weed seeds may be a viable weed management opportunity. He suggested that depletion of the weed seedbank by microorganisms should be integrated with other weed management strategies including germination stimulation, low rates of herbicides, manipulation of the soil environment, and biological control agents. Importantly, Kremer recommended more in-depth research on microbial factors affecting the soil weed seedbank.

Soil Fungi Population Density

Soil is a complex of interrelated communities of soil organisms which influence, yet are in part determined by, the chemical and physical parameters of the soil. The cycling of nutrients in soils of agricultural ecosystems is, to varying degrees, dependent on the energy supply to and through the soil biota (Buchanan and King 1992). Although microorganisms make up only 1 to 8% of the soil organic matter (SOM), they influence crop production by acting as catalysts for bio-transformations (Roder et al. 1988). Through the processes of decomposition, immobilization, and mineralization, soil microorganisms control the flow of carbon, nitrogen, phosphorus, and sulphur through the terrestrial ecosystem (Sarathchandra et al. 1988). Changing the crop management system will alter the soil microclimate and affect the soil biota (Paul and Clark 1989). In terms of biomass, not numbers, the fungi generally dominate the soil biota (Killham 1994). Fungi are eukaryotic and have septate mycelium or tubular mycelium that is multi-nucleate. Typically, a fungal hypha is 2-10 μm in diameter, with a cell dimension much greater than that of soil bacteria and actinomycetes (Killham 1994).

Changes in tillage practices bring changes in placement of plant residues in the soil profile (Bakermans and DeWitt 1970). Dawson et al. (1948) were among the first workers to study the effect of tillage on soil microflora. They reported that the top 2.5-cm of soil contained greater numbers of fungi, bacteria, and actinomycetes when the residues were left on the surface, whereas the 2.5- to 15-cm layer contained greater number of microorganisms when the residues were plowed under. Granatstein et al. (1987) suggested that seasonal changes must be taken into account when microbial biomass is compared.

Soil from a rotation of oat (*Avena sativa* L.) and red clover (*Trifolium pratense* L.) was found to have significantly higher fungal populations than soil from a system of continuous corn (Fraser et al. 1988). Broder and Wagner (1988) working with corn (*Zea mays* L.), soybeans (*Glycine max* L.) and wheat (*Triticum aestivum* L.) residues, reported environmental influence on specific fungal genera in Missouri. Corn residues tended to support a higher fungal population than soybean and wheat residue. *Penicillium* species were reported to be higher on residues during the growing season of each specific crop cultivated. *Aspergillus* species were found at the highest levels in all three crop residues in April and the lowest in September. *Trichoderma* species were isolated at high levels from corn plots during the summer months, but were a minimal portion of the overall fungal population isolated from corn residue.

Some herbicides are suspected to have stimulatory effects on population densities of some soil fungi, while others do not. Krzysko-Lupicka and Orlik (1997) reported a predominance of *Mucor*, *Trichoderma*, and *Fusarium* species to the exclusion of *Penicillium* and *Cladosporium* species in the media when glyphosate [N-(phosphonomethyl)glycine] was

used as sole phosphorus source. When glyphosate was used as the sole source of carbon, only *Rhizopus*, *Trichoderma*, and *Mucor* species survived. These results were in agreement with those reported by Wardle and Parkinson (1992) who reported that glyphosate could change the competitive saprophytic ability of soil fungi. Resident soil *Fusarium* species are also believed to increase in population through root colonization of glyphosate treated plants (Rahe et al. 1990). Ruppel et al. (1988) reported that minimum, moderate, and intensive use of the herbicide cyanazine, which is a member of the triazine family, had no detectable effect on soil population densities of *Fusarium* or *Trichoderma* species. They further noted that increases or decreases in fungal population densities apparently were completely independent of crop rotation and weed management densities under Colorado conditions. They suggested that changes in fungal population densities probably can be attributed to other environmental factors.

CHAPTER 2. WEED POPULATION DYNAMICS IN LAND REMOVED FROM THE CONSERVATION RESERVE PROGRAM

A paper accepted for publication in the Weed Science Journal[1]

Joel Felix and Micheal D. K. Owen

Abstract: A field study was established in southern Iowa in 1994 to study seasonal and long-term weed population dynamics on land being brought back into production after eight years as part of the conservation reserve program (CRP). The study was a split-plot design with four replications; two tillage regimes, two crop rotations, and three herbicide application methods. Even though tillage regime did not influence individual weed population density throughout the duration of the study, no till (NT) regime had more weeds compared to conventional tillage (CT). However, when weeds were grouped into categories, tillage influenced broadleaf weeds in 1994 and 1996 and total weeds in 1995. Plots under the NT regime had an average of 46 broadleaf weeds m^{-2} compared to 27 in CT in 1994 with common waterhemp being the most prevalent. No-tillage had a total of 186 weeds m^{-2} compared to 125 m^{-2} weeds in CT in 1995; however, in 1996 CT plots had 184 weeds m^{-2} compared to 121 m^{-2} in the NT regime. Except for broadleaf weeds in 1994, crop rotation did not influence the number of weeds, and herbicide application methods had the greatest impact on weed populations. Overall, weed populations were greater in 1997, 1996 and 1995

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compared with 1994 for all herbicide application methods. The no herbicide treatment had the highest number of weeds throughout the duration of the study. Total number of weeds in band and broadcast treatments averaged 41 and 26 weeds m^{-2} in 1994; 96 and 24 weeds m^{-2} in 1995; 96 and 12 in weeds m^{-2} 1996; and 109 and 95 in 1997 weeds m^{-2}, respectively. The use of broadcast herbicides under NT environment should be recommended for land coming out of CRP. Regardless of the herbicide application method or crop rotation, conventionally tilled plots had better yields for both corn and soybeans. Soybeans had a better stand compared to corn in the first year, indicating that a rotation starting with soybeans might be preferred in the land coming out of CRP.

Nomenclature: Common waterhemp, *Amaranthus rudis* Sauer AMATA; Corn, *Zea mays* L. soybeans, *Glycine max* L.

Key words: Conservation reserve program (CRP), common waterhemp, AMATA, no herbicide, banded, broadcast herbicide, big bluestem (*Andropogon gerardii* Vitman), smooth bromegrass (*Bromus inermis* Leyss), and yellow sweetclover (*Melilotus officinalis* Lam)

INTRODUCTION

Crop production systems that optimize yields while conserving soil and reducing pesticide contamination of ground and surface water is a goal of the agricultural community. The CRP was established in 1986 as a voluntary program to help farmers reduce soil erosion and adjust production of some agricultural commodities (USDA 1986). Beginning in September 1996, farmers could terminate the contracts and put the land into other uses or re-enroll with the program. Iowa had more than 810,000 ha under CRP, and surveys indicate

that about 50% of the producers intend to return some of the land to row crop production. Thus, research on lands previously under CRP is needed to determine how best to return the land to row-crop production while minimizing environmental problems related to soil erosion.

The ecology of weeds changes in response to the indigenous agricultural practices (Knab and Hurle 1986). This change is not understood fully and likely represents a major impediment to the successful implementation of conservation tillage systems. Growers may abandon NT systems because of weed problems that occur due to a knowledge void about changes in weed ecology. Further, it is possible that growers who are successful practitioners of NT make inappropriate use of herbicides due to the same knowledge void.

Tillage systems influence weed seed germination rates and the efficacy of weed control tactics, thus affecting weed populations. Because tillage greatly alters the environment, altering tillage systems favors certain weed life cycles over others (Buhler 1995). Froud-Williams et al. (1983) suggested that perennial grass and broadleaf weed populations increase when tillage is reduced. However, Buhler et al. (1994) reported that perennial weed populations did not change dramatically in response to tillage. Annual weed species also differ in response to tillage systems (Kotile 1992). Pollard and Cussans (1976) and Bachthaler (1974) reported that increasing tillage resulted in more broadleaf weed seedlings. Froud-Williams et al. (1983) found that weed seed populations declined in plowed locations compared with NT locations, although the percentage of decline varied by site. Owen (1992) observed greater grass and small-seeded annual broadleaf weed populations under NT compared with tilled systems. Cardina et al. (1991), and Mohler and Callaway

(1992) reported more weed seedlings in a NT environment. An increase in annual grass density under a NT environment has also been reported in a corn/soybean rotation (Wrucke and Arnold 1985).

Tillage also impacts the physical location of the weed seedbank. Wilson (1988) reported that reduced tillage left 50% of the weed seeds in the upper 7 cm of the soil, as compared with more intensive tillage systems where weed seeds were distributed evenly throughout the upper 30 cm. Burnside et al. (1986) reported that plowing reduced weed seed populations in the soil and that grass weeds were more affected than broadleaf weeds. However, it was suggested that despite a significant decline in the weed seedbank, growers should not reduce weed management strategies because the remaining weed seed population was sufficient to replenish the weed population rapidly. Schweizer and Zimdahl (1984) recommended that intensive weed management should be used for the first few years if a large weed seedbank exists but that less intensive strategies could be successful after the weed seedbank declined. However, they cautioned that if the environment impacted the weed management strategies negatively, new weed seeds were introduced via wind, contaminated crop seed or irrigation water, or where weed resistance to herbicides develops, the weed seedbank would increase rapidly and intensive management strategies would be necessary.

The seedbank of individual weed species and of the population as a whole in undisturbed, previously farmed land has been reported to decrease exponentially with time (Roberts and Feast 1973). In that study, weed seedbank was reported to decrease at an average of 12% per year in undisturbed soil, whereas the cultivated soil had an average

decrease of 32%.

The specific objective of this research was to determine the impact of a combination of two tillages, two crop rotations, and three herbicide application methods on seasonal and long-term weed population dynamics after eight years of CRP.

MATERIALS AND METHODS

A four year field experiment was conducted at the Iowa State University (ISU) McNay Memorial Research and Demonstration Farm near Chariton, Iowa, on land previously under CRP for eight years. The predominant soil was Shelby-Adair complex (Fine, montmorillonitic, mesic Typic Argiaquoll). The soil is low in permeability with clay content ranging between 30 and 40%. Soil tests indicated an average pH of 6.8, 4.5% organic matter, 76 kg ha^{-1} P, and 438 kg ha^{-1} K. No fertilizer was applied at planting time. The CRP cover was a mixed seeding of big bluestem (*Andropogon gerardii* Vitman), smooth bromegrass (*Bromus inermis* Leyss), and yellow sweetclover (*Melilotus officinalis* Lam). Also, other prairie forbs and deciduous trees had invaded the experiment area.

The experimental design was a split-plot and treatments were arranged in a randomized complete block with four replications. No till and CT formed the main plots, crop rotations (continuous corn and soybean/corn rotation), and herbicide application methods (no herbicide, banded, and broadcasted) formed the sub-plots. Plots measured 30.5- by 4.6-m and 15-m of the two center rows were harvested to determine crop yield.

Tillages were established in spring 1994 and maintained throughout the duration of the study. The entire experimental area was mowed and hay collected. Following regrowth

to about 15-cm, the NT plots were sprayed with glyphosate [N-(phosphonomethyl)glycine] at the rate of 1.69 kg a.i. ha^{-1} one week before planting. Moldboard plowing to a 15-cm depth followed by two disc cultivations comprised the CT plots in spring 1994, with some degree of difficulty due to heavy plant residue and wet conditions. Thereafter, a rotary mower was used in the spring of each following year to distribute the residue from the preceding crop over the plots before a field cultivator was used to create a smooth seedbed ready for planting. Corn and soybeans were planted at a depth of 5-cm at 64,200 and 345,940 seeds ha^{-1}, respectively, in rows spaced 76-cm during mid-May to mid-June each year, depending on the weather. The rotated crop was grown every other year and the available adapted soybean cultivar and corn hybrid was used. Thirty days after planting (DAP), corn plots received 135 kg N ha^{-1} in the form of anhydrous ammonia as a side dress application.

Herbicide treatments for corn were a mixture of acetochlor [*2*-chloro-*N*-(ethoxymethyl)-'(2-ethyl-6-methylphenyl)acetamide] and atrazine [*6*-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine] at 2.5 and 1.7 kg a.i. ha^{-1}, respectively. Soybean plots received a pre-emergence treatment of alachlor [*2*-chloro-*N*-(2,6-diethylphenyl)-'(2-methoxymethyl) acetamide] at the rate of 2.7 kg a.i. ha^{-1}. A 4.5-m boom equipped with six 80002EVS nozzles spaced at 76-cm apart was mounted on an all-terrain vehicle (ATV) to apply a 38-cm band over the row in all banded treatment plots. Similarly, a 4.5-m boom mounted on a tractor was used for broadcast (on both NT and CT plots) and glyphosate treatment on NT plots. Post emergence herbicide treatments were not applied due to windy conditions at the site, and thus, cultivation was done 20 DAP in both NT and CT each year. Also, a single hand weeding operation was done 30 DAP in the band and broadcast herbicide

plots as a post-emergence weed control measure. Crop population was determined by counting plants in 5.3-m on each of the two center rows 21 DAP each year.

Field Weed Counts

Weeds were counted at 29, 68, and 120 DAP, which coincided with corn at 10 leaves, tasseling, and physiological maturity (black layer), respectively. Three sub-samples per plot were counted in a 30 by 30-cm area chosen arbitrarily, and weeds were recorded by species as listed in Table 2.2.

Statistical Analysis

Individual weed species and grouped categories (broadleaf, grass, and total) were analyzed with a split-plot analysis of variance (ANOVA) model. The broadleaf weed category included: field bindweed *(Convolvulus arvensis* L.), common lambsquarters *(Chenopodium album* L.), common waterhemp, Pennsylvania smartweed (*Poligonum pensylvanicum* L.), Venice mallow (*Hibiscus trionum* L.), horsenettle *(Solanum carolinense* L.), common ragweed (*Ambrosia artemisiifolia* L.), horseweed (*Conyza canadensis* L.), prickly sida (*Sida spinosa* L.), and eastern black nightshade *(Solanum ptycanthum* Dun.). Grass weeds included giant foxtail *(Setaria faberi* Herrm.) and yellow foxtail (*Setaria glauca* (Weigel) Hubb.). Preliminary analysis of both square-root transformed and non-transformed data gave similar results (Ahrens et al. 1990). Thus, non-transformed data collected from 1994 to 1997 were used in ANOVA using the Statistical Analysis System (SAS), and means for both main and sub-plots were compared using the least significant difference (LSD) test

at $P \leq 0.05$ level of significance.

RESULTS AND DISCUSSION

Managing the CRP Cover

Visual assessment indicated that glyphosate applied in the spring of 1994 failed to completely kill the CRP cover in the NT plots (data not shown). As a result, plots under the NT environment had high infestations of big bluestem. However, the severity of infestation differed depending upon the herbicide application method used. The use of glyphosate in the succeeding years helped to eliminate the big bluestem in the NT plots. Plots that received no herbicide treatment had the highest big bluestem population, and the broadcast herbicide plots had the lowest. No regrowth was experienced in CT plots because all the vegetation was buried by moldboard plowing during land preparation. These results indicate that a single dose of glyphosate applied during spring did not give acceptable control of the CRP cover. This suggests that application of glyphosate in late fall followed by a second dose (as needed) in the following spring may be a better strategy to manage effectively the CRP cover.

Corn and Soybean Establishment

No-till plots had an average of 48,062 corn plants ha^{-1} in 1994, which was 19% less than the CT (data not shown). Also, corn in NT plots took two to three days longer to emerge than in CT, likely due to cooler soils and the thick residue ground cover (Johnson and Lowery 1985). There was no difference between tillage treatments for soybean populations.

First year soybean establishment was better than that of corn (data not shown) suggesting that a rotation starting with soybeans should be considered for land coming out of CRP. Tillage affected corn population in 1994 and 1997, but not in 1995 and 1996. Conventional tillage plots averaged 50,309 plants ha^{-1} in 1997, which was 19% less than that in NT plots. The difference may be attributed to less infiltration in CT plots due to heavy clay soils at the location. Corn in rotation with soybeans in 1995 had an average of 20,738 plants ha^{-1} which was 32% less than the continuous corn population. Regardless of the tillage regime, however, the corn population was much lower than intended in 1995 due to the excessive rainfall experienced at the beginning of the season (Table 2.1). The saturated, cold soil likely caused poor corn germination and emergence. Herbicide application methods did not affect plant populations of either corn or soybeans.

Weed Population Changes Over Time

There was a yearly variation in weed density (Table 2.2). Importantly, giant foxtail and common waterhemp populations increased over time. Giant foxtail averaged 6%, 13%, 37%, and 38% of the total weeds in 1994, 1995, 1996, and 1997, respectively. Common waterhemp on the other hand comprised 32%, 74%, 50%, and 51% of the total weeds in the same years. It has been estimated that weed populations and soil characteristics do not reach equilibrium until the management regimes have been established for 4 to 10 yrs (Clements et al. 1996). Thus, the increase in weed density with time in this study suggested that effects from different herbicide application methods had not reached their equilibrium.

Effect of Tillage on Weed Populations

Tillage did not influence individual weed populations in 1994, 1995, 1996, and 1997 (data not shown). However, tillage effects were observed in the broadleaf weed category in 1994 and 1996 and for total weeds in 1995 (Table 2.3). Tillage did not affect grass weeds in any of the years, but there was a general increase in population over time with NT having a higher population. Similar results were reported by Owen (1992) in non CRP conditions. In 1994, plots under NT and CT had an average of 46 and 27 broadleaf weeds m^{-2}, respectively. We attribute this to differences in common waterhemp population between the two tillage regimes.

In general, common waterhemp comprised an average of 50 and 44% of the broadleaf weeds observed in NT and CT plots, respectively. This difference can be attributed to the late emergence characteristics of common waterhemp compared to other annual weeds (Buhler et al. 1997). Also, tillage differences in weed seed placement may have contributed to the differences in germination (Wilson 1988; Buhler 1995). By germinating late, common waterhemp plants probably survived better in a NT environment than in CT because most of the herbicide may already have been degraded or bound to plant residues on the ground (Buhler 1995).

However, in 1996 there were more broadleaf weeds in the CT compared to NT. With 42 weeds m^{-2}, the NT plots had only 30% of the weeds recorded in CT plots (Table 2.3). Similar results were observed in 1997, but were not significantly different ($P \leq 0.05$). This was a reversal of a trend seen in the previous two years. Planting was done June 16, 1996 and thus most of the weeds had germinated prior to the glyphosate application. Also, it could

be due to differences in vertical weed seed distribution between the two tillage systems (Buhler 1995). The fact that weed seeds tend to be deposited on or near the soil surface in a NT environment (Wrucke and Arnold 1985), and given that we planted late in the season, most weed seeds could have germinated early in the season (Buhler and Gunsolus 1996) and were killed by the glyphosate treatment applied before planting. The increase in grass weeds was due mainly to a build up of giant foxtail over the three years of this study (Table 2.2). Buhler and Oplinger (1990) reported similar results in a non CRP production system.

Seasonal Weed Population Dynamics

A seasonal decline in weed population occurred in three years regardless of the herbicide application method used (Table 2.4). There were more weeds 29 DAP (corn ten leaf stage) and fewer 120 DAP (corn physiological maturity). The decline in weed numbers between 29 DAP and 68 DAP (tasseling stages) was attributed to the field cultivation operation. Similarly, the decline in weed population between the 68 DAP and 120 DAP could have been due to weed maturation and death over time. Plots that received a no herbicide treatment had the most weeds for all four weed categories. Only giant foxtail and common waterhemp populations were changed by herbicide application method 29, 68, and 120 DAP (Table 2.4). The no herbicide treatment had the highest population of giant foxtail, common waterhemp, grass species, broadleaf, and total number of weeds m^{-2}. However, except for common waterhemp, band and broadcast treatments had similar results. Also, common waterhemp comprised 64%, 49%, and 64% of the total weeds at 29 DAP. It also represented 59, 47, 41 and 45, 33, 9% of the total weeds at 68 and 120 DAP, respectively.

Overall, herbicide application methods had the greatest impact on weed population. Banded and broadcast herbicide treatments reduced the total weed population by 80% and 89%, respectively, at the 29 DAP (Table 2.4) compared to the no herbicide treatment. The same treatments reduced the total weed population by 78% and 92% at 68 DAP. At 120 DAP, the broadcast herbicide treatment reduced the total weed population by 85% and banded herbicide treatment by 75%. These results suggest that a broadcast herbicide treatment might be preferred to a band treatment.

Effect of Herbicide Application Method Over Time

Herbicide application method had the greatest impact on the number of weeds. Plots receiving no herbicide had the most weeds when compared to band and broadcast treatments (Table 2.5). The band and broadcast herbicide treatments exhibited no difference ($P \leq 0.05$) in the number of giant foxtail, yellow foxtail, field bindweed, common lambsquarters, yellow nutsedge, common ragweed, Pennsylvania smartweed, and grass weed species throughout the duration of this study. Common waterhemp was the dominant broadleaf weed. Also, the three herbicide application treatments differed in common waterhemp, broadleaf species, and total weed density in 1994 and 1995. However, band and broadcast treatments affected the same categories similarly in 1996 and 1997 (Table 2.5). Giant foxtail and common waterhemp were the only weeds showing an increase in population density with time. Also, large numbers for giant foxtail and common waterhemp significantly affected the density of grass, broadleaf, and total weed species regardless of the herbicide application method used. The increase in weed density with time was associated with the fact that yield, weed

populations, and soil characteristics do not reach equilibrium until the management regime has been established for 4 to 10 yrs (Clements et al. 1996).

Corn and Soybean Yields

Soybean yield in plots under NT environment differed from CT in 1994. Soybean plots within no herbicide and banded herbicide treatments resulted in similar yield (1.1 and 1.3 Mg ha^{-1}, respectively), and broadcast had 2.0 Mg ha^{-1} (Table 2.6). No difference in yield was recorded for soybeans raised under CT environment in 1994. Similar results were obtained in 1996, however, with an increase in soybean yield possibly due to crop rotation effects and better control of big bluestem in the NT environment.

Tillage did not significantly affect corn yield in any of the years ($P \leq 0.05$) even though CT plots tended to have greater yields. The three herbicide application treatments produced similar corn yields in 1994. When averaged across herbicide application treatments, NT and CT plots averaged 7.2 and 8.3 Mg ha^{-1}, respectively in 1994. Corn yield differences as affected by tillage in 1994, could be attributed to a low plant population in the NT plots at the beginning of the cropping season which likely was caused by cool soils and the heavy plant residue cover. Johnson and Lowery (1985) reported similar effects in NT while working in a non CRP environment. Also, the difference may be attributed to poor CRP cover control in the NT plots. Similarly, low soybean yields could be attributed to their inability to compete with big bluestem which tends to have a massive root system. There were no rotational benefits for corn yield realized in 1995 in either of the tillage regimes. In fact, continuous corn plots had better yield compared to corn following soybean (Table 2.6).

We attribute this to poor corn emergence in CT rotated plots which might have been caused by the higher than normal precipitation received at the beginning of the season in 1995 (Table 2.1). Also, high clay content of the soil at this location may have affected water infiltration in the CT plots, and thus, poor soil aeration, which affected corn germination. This could be the main reason for lower corn yields in 1995 when compared to 1994, 1996 and 1997. Also, the lower yields may have been a direct effect of early autumn frost during 1995 and by animal damage experienced at this location for the duration of this study.

Herbicide application methods had the greatest impact on corn yield (Table 2.6). The no herbicide treatment had the lowest corn yield almost all of the time throughout the duration of this study regardless of the tillage used. The banded and broadcast treatments produced similar corn yields most of the time. The no herbicide regime had lower yield due to high number of weeds during the growing season. The yield of soybeans following corn within NT plots was not different for no herbicide and banded herbicide treatment. However, yield within the CT plots was different for the three herbicide application treatments, with the broadcast treatment producing the highest yields. The low corn yield in no herbicide treatment in 1997 could be a direct effect of higher weed density which continued to build up with time.

The 8 yrs of CRP caused patchy weed distribution in the field and there was a great variation in weed population and distribution among plots. This could also be associated with differences in seed dormancy and longevity in the soil among different weed species. Therefore, spot application of herbicides might be appropriate for efficient management of some weeds. Unlike corn, there were no problem establishing soybeans in the first year of

this study, indicating that a rotation starting with soybeans will be preferred in lands previously under CRP. Importantly, soybeans also allow the use of cultural weed management strategies, and this might help reduce herbicide usage. Band and broadcast herbicides generally provided similar level of weed control for yellow nutsedge and grass weeds categories. Banded and broadcast herbicide treatments differed in the number of broadleaf weeds, indicating that broadcast treatment might be preferred. Tillage affected both weed populations and yield, with CT giving better yields than NT. However, because this land was taken out of production due to concerns for soil erosion, CT may not be an environmentally appropriate option.

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Table 2.1. Monthly precipitation and departure form 30 year average (in parenthesis) from 1993 to 1997 at the Iowa State University McNay Research and Demonstration Farm.

Month	Year				
	1993	1994	1995	1996	1997
	Monthly precipitation (cm)				
March	7.3 (+1.1)	0.5 (-5.8)	4.8 (-1.4)	4.9 (-1.3)	1.5 (-4.7)
April	6.3 (-3.0)	6.4 (-2.8)	12.1 (+2.8)	4.1 (-5.2)	6.5 (-2.8)
May	13.9 (+3.8)	8.7 (-1.4)	23.2 (+13.1)	17.3 (+7.3)	7.5 (-2.5)
June	8.3 (-4.0)	8.2 (-4.1)	18.2 (+5.9)	5.6 (-2.0)	10.1 (-2.2)
July	37.3 (+25.5)	6.8 (-2.9)	8.8 (-0.9)	4.8 (-5.0)	11.7 (+1.9)
August	23.8 (+13.6)	4.8 (+5.4)	6.2 (-4.0)	10.3 (+0.1)	7.3 (-2.9)
September	11.1 (-0.2)	4.8 (-6.8)	8.8 (-2.5)	8.7 (-2.6)	5.8 (-5.5)
October	2.7 (-3.8)	2.8 (-3.8)	3.9 (-2.7)	8.3 (+1.7)	12.5 (+5.9)
Total	110.7 (+33.0)	43.0 (-22.2)	86.0 (+10.3)	64.0 (-7.0)	62.9 (-8.1)

Table 2.2. Complete list of weed species and their average populations at the McNay Research and Demonstration farm from 1993 through 1997. Populations are averaged across tillages, cropping systems and weed management regimes.

			Average number of weeds m^{-2}			
Weed species	Species name	Code[a]	1994	1995	1996	1997
			weeds m^{-2}			
Giant foxtail	*Setaria faberi* Herrm.	SETFA	3 a[b]	20 b	56 c	108 d
Yellow foxtail	*Setaria glauca* (L.) Beauv.	SETLU	4 b	10 c	1 a	1 a
Field bindweed	*Convolvulus arvensis* L.	CONAR	9 b	<1 a	<1 a	13 b
Common lambsquarters	*Chenopodium album* L.	CHEAL	2 a	1 a	2 a	7 b
Common waterhemp	*Amaranthus rudis* Sauer	AMATA	17 a	115 c	77 b	145 c
Yellow nutsedge	*Cyperus esculentus* L.	CYPES	10 c	5 b	5 b	1 a
Venice mallow	*Hibiscus trionum* L.	HIBTR	2 a	2 a	4 b	1 a
Horsenettle	*Solanum carolinense* L.	SOLCA	2 b	1 b	1 b	<1 a
Prickly sida	*Sida spinosa* L.	SIDSP	<1 a	2 b	3 b	2 b
Common milkweed	*Asclepias syriaca* L.	ASCSY	<1 a	0 a	<1 a	3 b
Common ragweed	*Ambrosia artemisiifolia* L.	AMBEL	1 b	<1 a	2 c	1 b
Eastern black nightshade	*Solanum ptycanthum* Dun.	SOLPT	1 b	0 a	<1 a	<1 a

Table 2.2. (continued)

Weed species	Species name	Code[a]	1994	1995	1996	1997
			weeds m^{-2}			
Hemp dogbane	*Apocynum cannabinum* L.	APCCA	<1 a	0 a	<1 a	<1 a
Horseweed	*Conyza canadensis* (L.) Cronq.	ERICA	1 a	0 b	<1 b	<1 b
Pennsylvania smartweed	*Polygonum pensylvanicum* L.	POLPY	2 b	<1 a	2 b	2 b
Grass weed species	Not applicable	Not applicable	7 a	29 b	57 c	109 d
Broadleaf species	Not applicable	Not applicable	36 a	121 b	91 b	174 c
Total weed species	Not applicable	Not applicable	53 a	155 b	153 b	284 c

[a] Weed Science Society of America approved code; SETFA = *Setaria faberi*, SETLU = *Setaria glauca*, CONAR = *Convolvulus arvensis*, CHEAL = *Chenopodium album*, AMATA = *Amaranthus rudis*, CYPES = *Cyperus esculentus*, HIBTR = *Hibiscus trionum*, SOLCA = *Solanum carolinense*, SIDSP = *Sida spinosa*, ASCSY = *Asclepias syriaca*, AMBEL = *Ambrosia artemisiifolia*, SOLPT = *Solanum ptycanthum*, APCCA = *Apocynum cannabinum*, ERICA = *Conyza canadensis*, POLPY = *Polygonum pensylvanicum*. [b] Means within a row followed by the same letter are not significantly different according to the least significant difference (LSD) test; P = 0.05.

Table 2.3. Effect of tillage on weed population dynamics averaged across cropping systems, and weed management regimes.

	1994			1995			1996			1997		
	Tillage			Tillage			Tillage			Tillage		
Weed groups	CT[a]	NT	LSD[b]	CT	NT	LSD	CT	NT	LSD	CT	NT	LSD
	Number of weeds m^{-2}											
Grass species	6	8	NS[c]	16	43	NS	36	78	NS	104	113	NS
Broadleaf species	27	46	18	103	139	NS	140	42	39	178	171	NS
Total weeds	50	58	NS	125	186	50	183	121	NS	283	285	NS

[a] CT = Conventional tillage, NT = No tillage

[b] LSD = Least significant difference ($P \leq 0.05$), testing the means between tillages within a year

[c] NS=Not significantly different at $P \leq 0.05$

Table 2.4. Effect of weed management regime on different weed species averaged across years (1994 to 1997), cropping systems, and tillages at different days after planting (DAP).

	29 DAP				68 DAP				120 DAP			
Species	No Herb.[a]	Band	Full	LSD[b]	No herb.	Band	Full	LSD	No herb.	Band	Full	LSD
	Weeds m^{-2}				Weeds m^{-2}				Weeds m^{-2}			
SETFA[c]	157	31	5	32	97	24	1	32	90	13	<1	32
AMATA	346	52	37	3	200	35	11	3	98	18	3	3
Grass spp	164	33	7	31	105	27	3	31	98	16	1	31
Broadleaf spp	366	68	47	56	222	44	20	56	117	35	30	56
Total weeds	541	106	58	79	337	75	27	79	219	54	33	79

[a] No herb. = No herbicide, Band = Banded herbicides, Full = broadcast herbicides

[b] LSD = Least Significant Difference ($P \leq 0.05$) testing means within a row for different DAP

[c] SEFTA = *Setaria Faberi*, AMATA = *Amaranthus rudis*

Table 2.5. Effect of growing season and weed management regime on weed population density.

	1994				1995				1996				1997			
	Management				Management				Management				Management			
Species	1[a]	2	3	LSD[b]	1	2	3	LSD	1	2	3	LSD	1	2	3	LSD
	Weeds m^{-2}				Weeds m^{-2}				Weeds m^{-2}				Weeds m^{-2}			
SETFA	7	1	1	4	43	13	2	25	136	31	<1	69	272	44	7	110
SETLU	7	2	3	3	20	8	2	8	2	1	<1	2	2	1	<1	NS
CONAR	13	8	7	4	<1	<1	<1	NS	<1	<1	<1	NS	30	8	<1	28
CHEAL	3	2	1	2	1	<1	<1	NS	3	2	<1	NS	13	5	2	9
AMATA	32	14	6	7	272	63	11	41	210	19	3	49	344	44	48	103
CYPES	18	7	5	11	6	5	4	5	9	3	2	22	1	<1	2	NS
AMBEL	3	1	<1	2	<1	0	<1	NS	4	2	<1	NS	3	<1	<1	0
SOLPT	1	1	0	1	0	0	0	NS	<1	<1	0	NS	0	0	0	NS
POLPY	4	1	<1	2	<1	<1	<1	NS	4	2	<1	NS	4	2	1	3
Grass spp	14	3	3	6	63	22	3	37	138	32	1	70	274	45	7	110
Broadleaf	60	31	18	9	277	69	16	41	230	34	9	49	373	64	86	109
Total	92	41	26	14	345	96	24	54	377	69	12	61	648	109	95	104

[a] 1 = No, 2 = Banded, and 3 = broadcasted herbicide; averaged across tillage and cropping systems.

[b] LSD = Least significant difference ($P \leq 0.05$) for means within a row between management regimes within a year.

Table 2.6. Effect of weed management regimes, cropping system, and tillage on corn and soybean yields within a year.

Weed management regimes	1994				1995				1996				1997			
	CC[a]		SC		CC		CS		CC		SC		CC		CS	
	NT[b]	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT	NT	CT
	Yield Mg ha^{-1}															
No herbicide	6.0	6.8	1.1	2.2	1.9	2.4	1.6	2.2	7.2	5.6	2.3	1.8	4.0	3.5	6.8	4.9
Banded	7.8	8.8	1.3	2.6	2.9	4.3	2.3	2.0	9.1	10.4	2.2	2.6	11.3	10.0	12.4	10.4
Broadcast	7.7	9.3	2.0	2.7	3.4	4.6	2.6	3.0	8.6	9.5	3.3	3.5	10.5	11.0	12.5	12.7
LSD[d] (0.05)	NS[c]		0.5		1.2		1.2		2.3		0.7		0.2		0.2	

[a] CC = Continuous corn, SC = Soybeans after corn, CS = Corn after soybeans

[b] NT = No tillage; CT = Conventional tillage

[c] NS = Not significantly different ($P \leq 0.05$)

[d] LSD = Least significant difference ($P \leq 0.05$) is used to compare means within the two columns above it.

CHAPTER 3. WEED SEEDBANK DYNAMICS IN POST CONSERVATION RESERVE PROGRAM (CRP) LAND

A paper to be submitted to the Weed Science Journal for publication[1]

Joel Felix and Micheal D. K. Owen

Abstract: The influences of tillage, crop rotation, and weed management regimes on the weed seedbank in land previously under CRP were determined from 1994 through 1997. The study followed a split-plot design with four replications, two tillage, two cropping systems, and three weed management regimes. Eleven weed species were recorded in 1994 and 1995, and 13 in 1996 and 1997. The seedbank was dominated by broadleaf species throughout the duration of the study. In the first year out of CRP, the seedbanks for common lambsquarters and pigweeds were 10,365 and 31,925 seeds m^{-2}, respectively. The pigweed seedbank increased over time and climaxed at 51,670 seeds m^{-2} in 1996. The seedbank for foxtail species was only 417 seeds m^{-2} in 1994, but increased to 7,820 seeds m^{-2} in 1997. The dramatic buildup of foxtail species seedbank over the 4 yr period was mainly due to a large population increase in the no herbicide weed management regime. Band and broadcast herbicides had similar effects on the weed seedbank. Tillage and crop rotation did not influence the weed seedbank or Shannon's diversity index, nor did they interact with the

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weed management regimes in any of the years. The weed seedbank varied with years and time of soil sampling. Fall sampling tended to have a larger seedbank which declined significantly by the spring sampling. The no herbicide treatment also tended to have a more diverse weed seedbank compared to the weed seedbank from band and broadcast weed management regimes. There was an average of one grass and three broadleaf weed species in the three weed management regimes. The use of band and broadcast herbicides reduced the weed seedbank density but did not affect the number of broadleaf weed species.

Nomenclature: Common lambsquaters, *Chenopodium album* L. CHEAL; pigweed species, *Amaranthus spp*; foxtail species, *Setaria spp.*

Key words: Seedbank diversity, Shannon's diversity index, Margalef's D_{MG}, CHEAL, Conservation reserve program (CRP), big bluestem (*Andropogon gerardii* Vitman), smooth bromegrass (*Bromus inermis* Leyss), and yellow sweetclover (*Melilotus officinalis* Lam)

INTRODUCTION

Weeds are best described as a nuisance in agriculture because of their persistence in different cropping systems. The fate of a weed seedbank is controlled by several factors, including seed germination, predation from vertebrates and invertebrates, and infection by soil microorganisms (Cavers and Benoit 1989). Other factors include dormancy and loss of viability which are influenced by the physiological status of the seed and the environmental conditions in the soil (Schafer and Chilcote 1970).

Predicting potential weed emergence is a fundamental need for the development of integrated strategies for weed management (Cardina et al. 1996). If growers could predict the

composition and density of weed seedlings that will emerge during a growing season, they could plan and implement appropriate control measures only when and where necessary (Cardina and Sparrow 1996; Sagar and Mortimer 1976). Roberts (1970) suggested that the rate of weed seed loss from the soil seedbank followed an exponential decay curve, but varied for different species (Roberts and Feast 1972).

Egley and Chandler (1983) estimated that 12 yrs were required to reduce the soil seedbank of viable velvetleaf (*Abutilon theophrasti* Medicus) seeds to 99% of the original level. Also, Mester and Buhler (1990) reported low survival rate and establishment ability for velvetleaf seeds when left on the soil surface. Therefore, it is likely that the level of velvetleaf seedbank in the land coming out of CRP has declined due to lack of seed incorporation into the soil. Weed seeds that remain in the soil for an extended period tend to associate with soil particles and get incorporated in soil structural units (Pareja et al. 1985). This association may occur regardless of tillage.

The composition and density of the weed seedbank vary greatly and is closely linked to the cropping history (Holt 1988). Kelly and Bruns (1975) compared the weed seedbank of a grassland to an adjacent area subjected to 5 yrs of crop production. The weed seed population was four times greater in the cropped land compared to the grassland. Barnyardgrass [*Echinochloa crusgalli* (L.) P. Beauv.], common lambsquarters, and pigweeds comprised 90% of the weed seedbank in the cropland soils but were not present in the grassland soils.

Many weed seeds persist in the soil because the germination requirements are not met at the soil-seed microsite, and the seeds remain dormant (Pareja and Staniforth 1985). Also,

weed seed germination is affected by moisture and oxygen levels in the immediate vicinity of the seed (Pareja and Staniforth 1985). The oxygen status of the soil-seed microsite is affected by the soil water content and soil porosity.

Crop and weed management programs are closely linked and influence changes in the soil weed seedbank (Wilson 1988). Roberts (1970) reported that the number of weed seeds in the soil could be maintained at 25,000,000 ha^{-1} or less when appropriate use of herbicides and tillage were employed in conjunction with crop rotation. The primary reason for tillage and herbicide use, therefore, is to efficiently keep weeds at a manageable level in a crop field. However, the accepted advantages of no tillage crop production systems include reduced soil erosion, energy conservation, reduced soil compaction, reduced soil moisture evaporation, improved water infiltration, and less soil temperature fluctuation (Sen 1987). These advantages also are experienced by the weeds that are potentially placed in a superior competitive position in no tillage production systems (Froud-Williams et al. 1983). Cultivation, however, can induce weed seed germination, thus depleting the active seedbank (Wilson 1988). However, weed seed populations may remain stable due to other mechanisms such as dormancy and variable germination capabilities (Shaw and Hainero 1990). Therefore, it is fair to predict that weed seedbank in the land coming out of CRP is likely to have a seedbank different from continuously crop land.

Tillage systems influence weed seed germination rates and herbicide efficacy, thus affecting future weed populations. Tillage also impacts the physical location of the weed seedbank. Wicks et al. (1971) reported that as the intensity and frequency of tillage declines, the weed seedbank moves closer to the soil surface. Wilson (1988) suggested that reduced

tillage left 50% of the weed seeds in the upper 7-cm of the soil, as compared to more intensive tillage systems, where weed seeds were evenly distributed throughout the upper 30-cm of the soil profile. Pareja et al. (1985) found that soils under reduced tillage systems had an average of 24 seeds per 100 g soil; this represented a six fold increase in weed seed populations found in conventional tillage systems. Thus, it becomes more critical to manage weeds in no tillage systems than in production systems that include tillage.

Burnside et al. (1986) reported that plowing reduced the total weed seed populations in the soil and that grass weeds were more affected than broadleaf weeds. However, it was suggested that in spite of a significant decline in the weed seedbank, growers should not reduce weed management strategies as the remaining weed seed population was sufficient to rapidly replenish the weed population.

Schweizer and Zimdahl (1984) observed a decline in redroot pigweed (*Amaranthus retroflexus* L.) and *Chenopodium* spp. seeds by 34 and 22%, respectively, after one cropping year. However, the seedbank then remained stable until the fourth cropping year. After the sixth year, the weed seeds declined by 99 and 91% for redroot pigweed and *Chenopodium* spp., respectively. Schweizer and Zimdahl (1984) concluded that intensive weed management should be employed for the first few years if a large weed seedbank exists, but that less intensive strategies could be successful after the weed seedbank declined. He cautioned, however, that if the environment negatively impacted the weed management strategies, the weed seedbank will rapidly increase and intensive management strategies will become necessary.

Forcella and Lindstrom (1988) reported that when continuous corn and corn/soybean rotations were used both under conventional and ridge tillage systems, 1,500 to 3,000 weed seeds m^{-2} (to a depth of 10 cm) were observed in continuous corn under ridge tillage. Weed seed production was approximately 66% less in conventional tillage corn. Soil from the corn/soybean rotation contained 200 to 700 weed seeds m^{-2} regardless of tillage. Crookston et al. (1988) reported that the weed seedbank for continuous corn production systems was twice as large as the seedbank for crop rotation production systems. The objective of this study, therefore, was to evaluate the effects of tillage, crop rotation, and weed management regimes on weed seedbank dynamics in land previously under CRP.

MATERIALS AND METHODS

Site Description and Experiment Design

A field study was established at the Iowa State University (ISU) McNay Memorial Research Center near Chariton, Iowa, in the summer of 1994 on the land previously under CRP for 8 yrs. The predominant soil was Shelby-Adair silt loam (fine, montmorillonitic, mesic Typic Argiaquoll) with clay content ranging between 30 and 40%, pH 7.4, and 4.5% organic matter. Daily rainfall (maximum and minimum) data were obtained from a nearby weather station. The CRP cover was a mixed seeding of big bluestem (*Andropogon gerardii* Vitman), smooth bromegrass (*Bromus inermis* Leyss), and yellow sweetclover (*Melilotus officinalis* Lam). Tillage treatments were done in the spring of each year, and main plots and subplots were maintained in the same location and received the same tillage, crop rotation, and weed management throughout the duration of the study.

A split-plot experiment design was used and treatments were arranged in a randomized complete block. The study had four replications and plot size was 30.5- by 4.6-m. The main plots were no-tillage (NT) and conventional tillage (CT) and the sub-plots were two cropping systems (continuous corn and soybean/corn rotation) and three weed management regimes (no-herbicide, banded herbicides, and broadcast herbicides).

Conventional tillage plots were moldboard plowed in 1994, and disc cultivated at the beginning of each subsequent year prior to planting. No-till plots were mowed in 1994, and the hay collected. Following regrowth to 15 cm, plots were sprayed with glyphosate [N-(phosphonomethyl)glycine] at the rate of 1.69 kg a.i. ha^{-1} to kill the CRP cover. Pre-emergence herbicide treatments for corn were a mixture of acetochlor [*2*-chloro-*N*-(ethoxymethyl)-*'*(2-ethyl-6-methylphenyl)acetamide] and atrazine [*6*-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine] at 2.5 and 1.7 kg a.i. ha^{-1}, respectively. Soybean plots received a PRE treatment of alachlor [*2*-chloro-*N*-(2,6-diethylphenyl)-*'*(2-methoxymethyl) acetamide] at 2.7 kg a.i. ha^{-1}. Herbicides were broadcast or banded in a 38-cm band over the row. Also, a single hand weeding operation was done at 30 DAP in all banded and broadcast treatments as a post-emergence weed control measure.

Soil Sampling and Weed Seed Recovery

Soil sampling for seedbank characterization was done in May and October of each year starting in spring 1994. Twenty (3.79-cm diameter and 15-cm deep) sub-samples were taken in a zigzag fashion from each plot using a soil probe. Soil samples were transported in cool containers to campus where they were frozen and kept at -13 C until processed. Soil

samples were processed for seed recovery using the floatation method as described by Standifer (1980). Each sub-sample was placed in a beaker filled with 250 ml solution of sodium hexametaphosphate $(NaPO_3)_6$ (Calgon water softener) at the rate of 57 g L^{-1}. Following 30 min of stirring at 200 rpm on an orbital shaker, samples were washed through a 250 μm opening sieve. Thereafter, the debris containing the weed seeds was collected on three layers of cheese cloth and dried at room temperature. After drying, the samples were processed individually and seeds recorded by species.

Statistical Analysis

Preliminary analysis of both square-root transformed and non-transformed data gave similar results. Therefore, non-transformed data collected from 1994 through 1997 were used in statistical analysis (Ahrens et al. 1990; Finney 1989). A split-plot analysis model using PROC GLM was employed to analyze the weed species seedbank data using the SAS® system. Test of the weed seedbank diversity among different treatments was accomplished with the Shannon index of variability. The raw data for each species were used to calculate three diversity indices (Stevenson et al. 1997; Derksen et al. 1995; Magurran 1988). Shannon's diversity index (H′) is widely used for overall assessment of weed species diversity and was calculated as follows:

$$H' = (N \log N - \sum n \log n)N^{-1} \quad [1]$$

where N is the total weed density in a plot and n is the weed density of each species present in a plot. Species richness was estimated by the use of Margalef's D_{MG} index and calculated as follows:

$$D_{MG} = (S\text{-}1)\ (\ln N)^{-1} \qquad [2]$$

where S is the number of species in each plot and N is the total weed density in a plot.

RESULTS AND DISCUSSION

In the year preceding initialization of this study (1993), the rainfall from March through October was 33-cm above a 30 yr average; again in 1995 it was 10.3-cm above the 30 yr average (Table 3.1). The rainfall in 1994 was 22.2-cm below the 30 yr average, but no moisture deficit was experienced due to excess precipitation in the previous year. Rainfall was also somewhat low in 1996 and 1997, averaging 7- and 8-cm below the 30 yr average, respectively. These conditions affected the date of soil sampling, and it is likely that some seeds germinated at the beginning of the season before soil samples were taken for spring seedbank characterization.

Seedbank Characterization

Weed seedbank populations reflect seed biology as well as past and current management practices (Cavers and Benoit 1989). Seeds of thirteen weed species were recorded at this site from 1994 through 1997 (Table 3.2). The first year out of CRP (1994) the seedbank at this site contained foxtail species, witchgrass (*Panicum capillare* L.), common lambsquarters, pigweed species, Pennsylvania smartweed (*Polygonum pensylvanicum* L.), velvetleaf, field pennycress (*Thlaspi arvense* L.), yellow sweetclover (*Melilotus afficinalis* Lam), yellow woodsorrel (*Oxalis stricta* L.), smooth groundcherry (*Physalis subglabrata* Mackenz. and Bush), and wild mustard (*Brassica kaber* (DC.)

Wheeler). Roberts (1970) and Roberts and Feast (1972) indicated that the rate of weed seed loss from the soil seedbank follows an exponential decay curve and varies for different species. In the 8 yrs of CRP, broadleaf weeds survived at a higher rate compared to grasses. On the average, common lambsquarters and pigweed species dominated the seedbank with 82% of the total weed seedbank, with 11% yellow sweetclover which was seeded as part of the CRP cover (Table 3.2).

The larger common lambsquarters seedbank in 1994 could be explained by its ability to survive longer in the soil. Lewis (1973) reported that common lambsquarters buried for 20 yrs still had 23% viability. Common lambsquarters and pigweed species continued to dominate the seedbank with 80% of the total seedbank in both 1995 and 1996 and 73% in 1997. Similar results were reported by Ball (1992) in a non CRP field where the seedbank of a 3 yr continuous corn crop was dominated by one annual grass and two annual broadleaf weed species. Also, common lambsquarters is very prolific with an ability to produce 30,000 to 176,000 seeds per plant if shielded from herbicides (Harrison 1990).

Prevailing weather conditions and crop performance in the previous year played a very significant role in the changes of weed seedbank at this location. Grass weed species seedbank continued to increase with time, and the highest level was recorded in 1997 (data not shown). There was almost a 19 fold increase in foxtail populations from 1994 to 1997. This increase was mainly attributable to a large increase in the foxtail seedbank for the no herbicide treatment (Table 3.3). Also, the relatively low foxtail seedbank in 1994 when the land was returned from CRP to row crop production, supported the fact that grass weed species tend to have a shorter seed life in the soil compared to broadleaf weed seeds (Lewis

1973). Higher seedbanks for yellow sweetclover, field pennycress, common lambsquarters, and *Amaranthus* spp. were observed in 1996. This increase was a consequence of poor weed control in 1995, due to higher rainfall at the beginning of the season (Table 3.1). Higher rainfall also resulted in poor corn emergence, thus weeds that escaped control strategies were able to flourish later in the season under a poor corn canopy cover.

Also, as a result of poor weed control in 1995, Venice mallow (*Hibiscus trionum* L.) and common ragweed (*Ambrosia artemisiifolia* L.) which had been controlled well in the previous years were first recorded in the plots in 1996. Their population remained relatively unchanged in 1997. Yellow sweetclover seeded as part of the CRP cover, had higher seed populations in 1994 and again in 1996 following a poor weed control in 1995. Velvetleaf seed population did not increase like that of common lambsquarters and pigweeds in this study, possibly due to the fact that competition from corn will reduce potential velvetleaf seed production over 90% in CT and NT systems (Cardina et al. 1995).

There was a decline in the total weed seedbank in 1995, possibly due to higher precipitation early in the season which resulted in seed germination before spring soil sampling for seedbank characterization. The seedbank increase in 1996 was attributed to poor corn and soybean stands in the previous year (data not shown), which resulted in a favorable environment for weed seed production. The decline in total weed seedbank in 1997 was associated with better weed control in 1996.

Effect of Tillage and Crop Rotation

Even though tillage and crop rotation are known to influence the weed seedbank composition (Ball 1992; Mulugeta and Stoltenberg 1997), there was no tillage or crop rotation main effects nor any interactions in this study. Thus, means were pooled over weed management regimes. The probable reason for this could be a late planting date in 3 out of 4 yrs of this study. Due to late planting, NT plots which tend to be colder at the beginning of the season had warmed up and thus weed seeds germinated equally in NT and CT at planting time. Also, CT plots were moldboard plowed only in 1994, and field cultivated in subsequent years to prepare the seedbed. We feel that field cultivation did not create enough soil inversion in the CT plots to create any differences between the two tillage systems. Also, it has been estimated that weed populations and soil characteristics do not reach equilibrium until the management regimes have been established for 4 to 10 yrs (Gebhardt et al. 1985). Similarly, in order for crop rotation to affect the weed seedbank, the rotation sequence must include crops that differ in planting and maturation dates, competitiveness, and associated management practices. In this study, both corn and soybeans were planted at the same time in all the years, and as such, there was no difference between the two cropping systems.

Effect of Weed Management Regimes

In 1994 and 1995, weed management regimes had no effect on weed seedbanks for common lambsquarters, velvetleaf, field pennycress, yellow sweetclover, yellow woodsorrel, smooth groundcherry, wild mustard, Venice mallow, and common ragweed (data not shown).

However, seedbanks for witchgrass, *Setaria* spp, *Amaranthus* species, and Pennsylvania smartweed differed in response to weed management regimes (Table 3.3). With very few exceptions, the no herbicide treatment had the highest seedbank throughout the duration of this study (Table 3.3). Band and broadcast herbicide treatments had similar effects on foxtail species seedbanks in 1994, 1996, and 1997. There was a dramatic increase of foxtail seedbank in the no herbicide treatment over time from 901 seeds m^{-2} in 1994 to 2,720, 14,603, and 20,896 seeds m^{-2} in 1995, 1996, and 1997, respectively. The banded herbicide treatment had 249, 1,244, 2,787, and 2,417 seeds m^{-2} in 1994, 1995, 1996, and 1997, respectively. There was a 224% increase in foxtail seedbank between 1995 and 1996 due to poor weed control in 1995. The broadcast herbicide treatment had the lowest foxtail seedbank of only 102, 112, 305, and 148 seeds m^{-2} in 1994, 1995, 1996, and 1997, respectively. The witchgrass seedbank had mixed results in that similar seedbanks were recorded in no herbicide and band; at the same time there was no difference in seedbank between band and broadcast treatments.

There was a large increase in *Amaranthus* species seedbank in the no herbicide treatment starting at 40,346 seeds m^{-2} in 1994, increasing to 59,019 and 93,502 seeds m^{-2} in 1995 and 1996, respectively. However, the *Amaranthus* seedbank declined to 61,965 seeds m^{-2} in 1997, possibly due to excessive competition from the *Setaria* spp. population which was very high in the no herbicide treatment.

The Pennsylvania smartweed seedbank also was high in the no herbicide treatment starting at 1,095 seeds m^{-2} in 1994. The seedbank was at 1,205, 924, and 1,486 seeds m^{-2} in 1995, 1996, and 1997, respectively. The band and broadcast herbicide treatments had similar

effects on the Pennsylvania smartweed seedbank in 1994, 1995, and 1997. In 1994, band and broadcast treatments had 74 and 67% of the seedbank observed in the no herbicide treatment, whereas in 1995 it was 56 and 40%, and 40 and 11% in 1997. There was no difference in Pennsylvania smartweed seedbank between no herbicide and band treatments in 1996.

The field pennycress seed population showed no response to weed management regimes in 1994 and 1995, but was high in the no herbicide treatment in 1996 and 1997. The field pennycress seedbank was at 4,583 and 4,352 seeds m^{-2} for no herbicide treatment in 1996 and 1997, respectively. The band and broadcast herbicide treatments had similar effects and averaged 927 and 497 weed seeds m^{-2} in 1996, and 892 and 437 in 1997, respectively. The yellow sweetclover seedbank was not affected by the three weed management regimes in 1994 and 1995 (data not shown). However, in 1996, the three weed management regimes affected the yellow sweetclover seedbank differently. The broadcast herbicide treatment had 4,841 seeds m^{-2} while band and no herbicide treatments had 5,160 and 6,045 seeds m^{-2}, respectively. These differences were not observed in 1997.

These results are supported by reports that herbicide use will influence seed numbers and weed species composition of a seedbank (Ball 1992). As an example, foxtail species increased by 2,319% between 1994 and 1997 in the no herbicide treatment, compared to 971% and only 145% for band and broadcast treatment, respectively. Also, these results support the idea that weed management practices influence the rate of change for individual weed species in the seedbank (Ball 1992).

To further analyze the weed seedbank, we grouped the weeds into grass species, broadleaf weeds, and total weeds (Table 3.3). Grass weed species as a group exhibited a

similar trend to that of *Setaria* species which dominated this group throughout the duration of this study. Also, to a great extent, broadleaf weeds were influenced by the *Amaranthus* species seed population. Differences in weed seedbank among the three weed management regimes were detected for broadleaf weed group in 1995 and total weed seedbank in 1995 and 1997 (Table 3.3). Common waterhemp (*Amaranthus rudis* Sauer) was the most prevalent weed in the *Amaranthus* species throughout the duration of this study. This is mainly due to its ability to germinate later in the season compared to other broadleaf weeds (Buhler et al. 1997). Its biology, therefore, might have contributed to the large build up of the *Amaranthus* species seedbank between 1994 and 1997. There was an average annual increase of 177% and 121% for pigweed species seedbank between 1994 and 1997 for no herbicide and band herbicide treatments, respectively. In contrast, the broadcast herbicide treatment had a 31% decline in *Amaranthus* species seedbank for the same period. These results suggest that broadcast herbicide treatment was more effective on pigweed control than the other two regimes.

Effect of Soil Sampling Time on Seedbank

Time of soil sampling for weed seedbank characterization had a large influence on the weed seedbank for *Setaria* species, common lambsquarters, *Amaranthus* species, field pennycress, yellow sweetclover, yellow woodsorrel, and witchgrass (Table 3.4). The *Setaria* species seedbank was higher for the fall sampling of each year and relatively low in spring reflecting the effect of annual seed-rain and degradation processes on the seedbank. The fall *Setaria* seedbank was 718, 2,319, 9,509, and 12,859 seeds m^{-2} in 1994, 1995, 1996, and 1997,

respectively. On average, spring sampling had 61% of the *Setaria* species seedbank observed in the previous fall sampling. Witchgrass seedbank was 264, 1,017, and 120 seeds m^{-2} in the fall of 1994, 1995, and 1996, respectively. It declined by 46, 53, and 19% in the springs of 1995, 1996, and 1997, respectively. Similar results were observed when all grass species were analyzed together as a group. We suspect that such a large discrepancy in seedbank between seasons can only come as a result of predation by small animals, early spring emergence, and insects that use weed seeds as a food source.

The pigweed seedbank was 49,189 seeds m^{-2} in the spring season 1994 when the study was initiated, and decreased to 14,666 seed m^{-2} in fall 1994, possibly due to the effects of weed management regimes. In spring 1995 and 1996 the pigweed species seedbank was at 29,990 and 43,106 seeds m^{-2}, respectively. The seedbank increased by 149 and 140% in the fall of 1995 and 1996, respectively. There was no difference in *Amaranthus* species seedbank between spring and fall sampling in 1997 possibly due to timely planting giving the crop a competitive advantage over the *Amaranthus* species.

Common lambsquarters seedbank results were mixed; there was no difference between spring and fall samplings in 1996 and 1997, but the seedbank differed slightly in 1994 and 1995. Less fluctuation in common lambsquaters seedbank between sampling times suggests the ability of common lambsquarters to last longer in the seedbank. Lewis (1973) reported a 23% survival rate for common lambsquaters following a 20 yr burial. In 1994 and 1995, 70% of the fall seedbank was observed the following spring season. The seedbank for common lambsquarters in 1994 and 1995 was 8,393 and 3,959, respectively. In the fall season of the same years, the seedbank was 12,337 and 5451 seeds m^{-2}.

The field pennycress seedbank, a winter annual, was 461 seeds m^{-2} in spring 1994 and 116 seeds m^{-2} in the fall sampling. In 1995, field pennycress seedbank was 108 seeds m^{-2} and increased to 2,184 seeds m^{-2} in the fall sampling. The field pennycress seed population was 1,191 and 2,801 seeds m^{-2} in spring and fall 1996, respectively. There was no difference in field pennycress seedbank between the two samplings in 1997. No differences in yellow sweetclover and yellow woodsorrel seedbanks were detected between spring and fall samplings in 1995, 1996, and 1997.

Overall, common waterhemp dominated the broadleaf species and had a larger seedbank in each fall season which declined an average of 18% by the following spring. The grass species seedbank had an annual average decline of 20% between fall and spring samplings and was dominated by giant foxtail (*Setaria faberi* L.). There was a 25% average total seedbank decline between fall and spring from 1995 to 1997.

Weed Seedbank Diversity and Richness

The study of community diversity considers the number of species within a community and an assessment of the proportional representation of these species (Magurran 1988). Shannon's H′ (Formula 1) is widely used to study species diversity in a community, whereas Malgaref's D_{MG} (Formula 2) is used to study species richness (Magurran 1988). Just as for weed seedbank means, the tillage and cropping systems did not affect the weed diversity (data not shown). Greater weed abundance (Table 3.3) and species richness (Table 3.5) explained the larger Shannon's H′ for broadleaf and total weed species (Table 3.5) compared to that for grasses.

According to Shannon's H', only weed management regimes affected the seedbank diversity. The no herbicide treatment had a more diverse grass weed seedbank compared to band and broadcast herbicide treatments from 1994 to 1996. There was no difference in seedbank diversity among management regimes in 1997 or for broadleaf species in 1994. However, in 1995 through 1997, the broadleaf species exhibited a similar trend to that of grasses. In that period, the broadleaf weed diversity was low in the no herbicide treatment and higher in band and broadcast treatments which had similar results. Since the magnitude of Shannon's H' is affected by the distribution of data (Zar 1996), the observed increase and dominance of the seedbank by pigweed species over the years (Table 3.3) in the no herbicide treatment likely contributed to the decline in diversity when compared to band and broadcast. Total weed seedbank diversity was similar for the three weed management regimes from 1995 through 1997.

Even though the use of herbicides tends to reduce the weed seed population density, it does not eliminate weed species (Fryer and Chancellor 1970; Derksen et al. 1995). In this study the use of band and broadcast herbicides reduced the total weed density, but did not affect the number of broadleaf weed species (Table 3.5). The no herbicide treatment had the greatest number of grass species, whereas the broadcast treatment had the least and banded had an intermediate number of grass species. Total weed species diversity was similar for the band and broadcast treatments, but higher in the no herbicide treatment in 1995 through 1997.

Weed community richness (Margalef's D_{MG}) was higher in the no herbicide treatment for the grass species seedbank and lower in the broadcast treatment. These results suggest

that the herbicides used in this study were very effective on grass species. Broadleaf weed seedbank richness decreased in the no herbicide treatment, but there was no difference in species richness between band and broadcast treatment in 1995 and 1996 (Table 3.5). For the total weed seedbank, however, there were no differences in species richness among treatments in 1996 and 1997. Overall, the broadleaf weed seedbank was affected differently by weed management treatments compared to grass species. The use of band and broadcast treatments is likely to lower the number of weed species, decrease weed species evenness, and maintain species richness.

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Table 3.1. Precipitation and departure form 30 yr average (in parenthesis) from 1993 through 1997 at the Iowa State University McNay research and demonstration farm.

Month	Year				
	1993	1994	1995	1996	1997
	(cm)				
March	7.3 (+1.1)	0.5 (-5.8)	4.8 (-1.4)	4.9 (-1.3)	1.5 (-4.7)
April	6.3 (-3.0)	6.4 (-2.8)	12.1 (+2.8)	4.1 (-5.2)	6.5 (-2.8)
May	13.9 (+3.8)	8.7 (-1.4)	23.2 (+13.1)	17.3 (+7.3)	7.5 (-2.5)
June	8.3 (-4.0)	8.2 (-4.1)	18.2 (+5.9)	5.6 (-2.0)	10.1 (-2.2)
July	37.3 (+25.5)	6.8 (-2.9)	8.8 (-0.9)	4.8 (-5.0)	11.7 (+1.9)
August	23.8 (+13.6)	4.8 (+5.4)	6.2 (-4.0)	10.3 (+0.1)	7.3 (-2.9)
September	11.1 (-0.2)	4.8 (-6.8)	8.8 (-2.5)	8.7 (-2.6)	5.8 (-5.5)
October	2.7 (-3.8)	2.8 (-3.8)	3.9 (-2.7)	8.3 (+1.7)	12.5 (+5.9)
Total	110.7 (+33.0)	43.0 (-22.2)	86.0 (+10.3)	64.0 (-7.0)	62.9 (-8.1)

Table 3.2. Weed species and seedbank populations at the McNay Research and Demonstration Farm, 1994 through 1997. Means are averaged across tillage, cropping systems and weed management regimes.

Weed species	1994	1995	1996	1997
	seeds m^{-2}			
Setaria spp.	417 a[a]	1359 a	5899 b	7820 b
Panicum capillare L.	142 a	579 b	302 b	167 a
Chenopodium album L.	10365 a	1980 c	9207 ab	7033 b
Amaranthus spp	31927 a	37329 a	51670 b	35694 a
Polygonum pensylvanicum L.	881 a	785 ab	616 b	745 ab
Abutilon theophrasti Medicus	73 a	45 ab	13 b	36 ab
Thlaspi arvense L.	289 a	1146 b	1996 c	1894 bc
Melilotus officinalis (L.) Lam	5685 c	5093 ab	5349 bc	4607 a
Oxalis stricta L.	618 c	384 b	284 ab	237 a
Physalis subglabrata	36 a	76 c	61 ab	78 c
Brassica kaber	4 a	132 b	248 c	64 ab
Hybiscus trionum L.	ND[b]	ND	57 b	51 b
Ambrosia atermisiifolia L.	ND	ND	83 b	116 b
Unknown	1044 b	491 a	371 a	364 a
Grass species	559 a	1938 a	6200 b	7988 b
Broadleaf species	49877 a	46970 a	69442 b	50390 a
Total weeds	51480 a	49399 ab	76013 c	58742 b

[a] Means within a row followed by the same letter are not significantly different according to he least significant difference (LSD = 0.05). [b] None detected.

Table 3.3. Effect of weed management regimes on weed seedbanks at the McNay Research and demonstration Farm, 1994 to 1997. Means are averaged across tillage and cropping systems within management regimes and year, 1994 through 1997.

	1994				1995			
	Management				Management			
Species/Code[a]	No herbicide	Banded	Broadcast	LSD[b]	No herbicide	Banded	Broadcast	LSD
	Seeds m^{-2}							
Setaria spp	901	249	102	653	2720	1244	112	1736
PANCA	292	97	36	215	1338	226	174	673
Amaranthus spp	40346	28406	27030	6765	59019	32198	20770	11847
POLPY	1095	809	739	276	1205	674	476	383
THLAR	242	393	231	269	1572	1506	361	1686
Grass species	1194	346	138	666	4058	1470	286	1934
Broadleaf spp	59015	46847	43769	8534	67574	43703	29632	12314
Total	61255	48414	44773	8709	72263	45554	30379	12269

[a] WSSA code; PANCA = *Panicum cappilare* L.; POLPY = *Polygonum pensylvanicum* L.; THLAR = *Thlaspi arvense* L.; MEUOF = *Melilotus officinalis* L.; and PHYSU = *Physalis subglabrata* L.

[b] Least Significant Difference ($P \leq 0.05$) testing means within a row and year.

Table 3.3. (continued)

	1996				1997			
	Management				Management			
Species/Code	No herbicide	Banded	Broadcast	LSD	No herbicide	Banded	Broadcast	LSD
	Seeds m^{-2}							
Setaria spp	14603	2787	305	9153	20896	2417	148	6469
PANCA	731	102	72	402	388	65	49	NS
Amaranthus spp	93502	39745	21762	30191	61965	31501	13616	15494
POLPY	924	625	297	324	1486	590	166	721
THLAR	4583	927	477	2485	4352	892	437	2841
MEUOF	6045	5160	4841	1023	4937	4463	4422	NS
PHYSU	94	46	44	46	62	89	83	NS
Grass species	15334	2858	408	9180	21284	2482	197	6368
Broadleaf	112694	55902	39729	32791	78007	44838	28326	19650
Total	128529	59074	40435	33267	99731	47652	28843	18145

Table 3.4. Seasonal effect on weed seedbank averaged across cropping systems, tillage and weed management regimes.

	1994			1995			1996			1997		
Weed groups	Spring	Fall	LSD[a]	Spring	Fall	LSD	Spring	Fall	LSD	Spring	Fall	LSD
	Number of seeds m^{-2}											
Setaria spp	117	718	542	398	2319	1573	2288	9509	6979	2781	12859	3903
CHEAL	8393	12337	2316	3959	5451	1455	9458	8956	NS	7634	6432	NS
Amaranthus spp	49189	14666	9061	29990	44667	7817	43106	60233	11371	34133	37255	NS
THLAR	461	116	324	108	2184	1428	1191	2801	1206	1821	1966	NS
MEUOF	3566	7804	1001	5142	5044	NS	4950	5747	NS	4557	4658	NS
OXAST	910	326	163	314	454	NS	239	328	NS	279	195	NS
PANCA	20	264	190	142	1017	520	483	120	320	97	237	NS
unknown	1449	640	311	522	460	NS	351	391	NS	499	230	219
Grass species	136	982	554	540	3336	1801	2771	9629	NS	2879	13096	3831
Broadleaf spp	63642	36112	9799	40451	53488	8655	59982	78982	12964	49095	51685	NS
Total weeds	65227	37734	9900	41513	57284	9135	63103	88922	14369	52473	65011	11325

[a] LSD = Least significant difference ($P \leq 0.05$), testing the means within a row and year

[b] NS=Not significantly different at $P \leq 0.05$

Table 3.5. Mean Shannon's H′, Margalef's D_{MG} indices, and number of weed species in three weed management regimes for grass, broadleaf, and total weed species at the McNay Research and Demonstration Farm, 1994 through 1997.

Management	Shannon's H′			Malgaref's D_{MG}			Number of species		
	Grasses[a]	Broadleaf[b]	Total[c]	Grasses	Broadleaf	Total	Grass	Broadleaf	Total
							Number		
				1994					
No herbicide	0.11	0.34	0.54	0.006	0.22	0.25	0.31	3.29	3.60
Banded	0.05	0.34	0.50	0.003	0.21	0.22	0.15	3.16	3.32
Broadcast	0.04	0.32	0.43	0.001	0.19	0.20	0.11	3.00	3.10
LSD (0.05)	0.04	0.02	0.07	0.001	0.01	0.01	0.11	0.13	0.17
				1995					
No herbicide	0.19	0.19	0.44	0.02	0.17	0.23	0.69	2.80	3.48
Banded	0.09	0.27	0.42	0.01	0.18	0.21	0.33	2.88	3.21
Broadcast	0.04	0.26	0.37	0.001	0.17	0.18	0.17	2.70	2.87
LSD (0.05)	0.05	0.05	0.12	0.01	0.04	0.04	0.15	0.39	0.44

Table 3.5. (continued)

	Shannon's H′			Malgaref's D_{MG}			Number of species		
	Grass[a]	Broadleaf[b]	Total[c]	Grass	Broadleaf	Total	Grass	Broadleaf	Total
							N umber		
					1996				
No herbicide	0.07	0.25	0.32	0.13	0.58	0.75	0.89	3.47	4.37
Banded	0.03	0.32	0.36	0.05	0.67	0.76	0.41	3.29	3.70
Broadcast	0.01	0.32	0.37	0.02	0.72	0.76	0.18	3.27	3.45
LSD (0.05)	0.02	0.05	0.05	0.05	0.08	0.09	0.22	0.39	0.48
					1997				
No herbicide	0.03	0.25	0.35	0.08	0.57	0.72	0.85	3.28	4.13
Banded	0.02	0.29	0.33	0.04	0.63	0.72	0.38	3.08	3.46
Broadcast	0.01	0.33	0.36	0.01	0.68	0.71	0.12	2.97	3.09
LSD (0.05)	0.02	0.05	0.06	0.03	0.10	0.12	0.20	0.46	0.58

[a]Grass species

[b]Broadleaf species

[c]Total weed species

CHAPTER 4. WEED SEEDBANK COMPARISON IN CONSERVATION RESERVE PROGRAM LAND AND ADJACENT CONTINUOUSLY CULTIVATED FIELDS

A paper to be submitted to the Weed Science Journal for publication[1]

Joel Felix and Micheal D. K. Owen

Abstract: In the summers of 1997 and 1998, 1,260 soil samples were taken from 63 of 99 Iowa counties to characterize the weed seedbanks in the land under continuous cultivation and that in the conservation reserve program (CRP) initiated in 1986. Iowa's nine crop reporting districts were used in this survey. A total of 18 weed species which included five grass and 13 broadleaf species was recorded in both the CRP and cropped fields. However, differences in weed seedbanks between CRP and adjacent cultivated fields were evident only for *Setaria* species, common lambsquarters, *Amaranthus* species, and yellow sweetclover. Cultivated fields tended to have a larger seedbank than CRP land. Only the northwest Iowa district had a larger *Setaria* species seedbank in CRP than in adjacent cultivated fields. In the north, central, and south districts, the common lambsquarters seedbank was higher in the cultivated fields than in adjacent CRP land. The *Amaranthus* species seedbanks were higher in the cultivated fields than adjacent CRP fields in the northeast, central, south, and southwest districts of Iowa. Generally differences in seedbanks among the nine crop

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reporting districts were more pronounced in the central one-third of Iowa. Yellow sweetclover seedbank was higher in CRP land than adjacent cropped fields because it was seeded as part of the CRP cover. Broadleaf weeds comprised 90% of the seedbanks in all districts. Establishment of good cover at the beginning of the CRP program likely reduced the weed seedbank in the surveyed field.

Nomenclature: Foxtails, *Setaria spp*; Common lambsquaters, *Chenopodium album* L., CHEAL; Pigweeds, *Amaranthus spp*; yellow sweetclover, *Melilotus officinalis* L., MEUOF.

Key words: Conservation reserve program (CRP), no herbicide, banded herbicide, broadcast herbicide, smooth bromegrass (*Bromus inermis* Leyss), and yellow sweetclover (*Melilotus officinalis* Lam), seedbank diversity, Shannon's diversity index.

INTRODUCTION

Weed surveys provide quantitative information on weed communities that is useful for evaluating changes in weed flora over time, developing integrated weed management strategies, and mapping weed populations (Schweizer et al. 1998). The land where CRP was established in 1986 as part of the United States Food Security Act of 1985 now can be returned to row crop production. It is estimated that 50% of the producers will return the land previously under CRP to annual crop production (Harris 1991). Information on the weed seedbank composition of CRP land, therefore, is very important to those who will be advising producers on how to manage the weeds when the land is returned to row crop production. In 1993, Iowa had about 900,000 ha enrolled in the CRP. The southern one-third of the state has the largest area in CRP, while the central tier and the upper third have

considerably less.

The annual rainfall ranges from 63 cm in northwest (NW) Iowa to 94-cm in eastern (E) Iowa[1]. In NW Iowa, approximately 76% of the total precipitation occurs during April through September. In E Iowa, 67% of the total precipitation occurs during the crop growing season. Iowa landscapes are dominantly level to gently sloping. Approximately 60% of the land has slope gradients between 0 to 5%. Another 16% of the land has slope gradient between 5 to 9%. The remaining 25% of the land has slopes greater than 9%. Most of this steeper land occurs in all or parts of the area distributed across 5 northeastern (NE) Iowa counties, 8 southern (S) counties, and 17 southwestern (SW) and western (W) counties. Mollisols represent the greatest number of the twelve soil series and these prairie derived soils are distributed across the entire state (Figure 4.1).

Formerly cultivated areas that have been seeded to winter pasture grasses should exhibit fewer weed species characteristic of cropped land. This is because the annual weed seed rain typical for cropped fields should be curtailed in the land under CRP. However, the likelihood that weed seeds will remain dormant deep in the soil profile is very high (Lewis 1973). The fate of viable weed seeds incorporated in the soil profile is determined by their internal physiology as well as conditions encountered in the soil (Schafer and Chilote 1970). Weed seeds that remain in the soil for a period of years become incorporated into the soil structural units (Pareja and Staniforth 1985).

Seed survival following many years of burial has been reported by a number of

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[1] Miller, G. A., Professor and extension Agronomist, Department of Agronomy, Iowa State University. Personal communication, 1998.

researchers. In an experiment initiated by Beal in 1879, at least one seed in 8 of 20 weed species germinated after 40 yrs of burial (Kivilaan and Banurski 1981). Thomas et al. (1986) reported green foxtail (*Setaria viridis* L.) viability following 17 yrs of burial. Lewis (1973) reported 23% viability in common lambsquarters following 20 yrs burial. He also reported very low seed longevity for grass species.

In non-cultivated areas like CRP, many weed seeds will not germinate because crucial cues necessary to break dormancy are lacking. Thus, the majority of all buried weed seeds will die within a few years. However, significant seed numbers of some species located in suitable microsites can survive for decades (Cavers 1994). Also, seeds buried at greater depths tend to remain dormant and viable longer, but few geminate and emerge successfully. Even though it has been suggested that dormancy in the majority of buried weed seeds is enforced primarily by a lack of light, many weeds successful in arable land and pastures may start germination in darkness if temperature fluctuations are experienced (Thompson and Grime 1983). Thus, many CRP fields are likely to have a weed seedbanks different from that observed in adjacent cropped land.

Thompson and Grime (1979) divided seedbanks into two main categories. Viable weed seeds in transient (active) seedbanks will germinate or die within a year. Alternatively, persistent (inactive) seedbanks have some seeds survive in the soil for 2 or more years before they germinate and establish as seedlings. Thus, in CRP it is the species with persistent seedbanks that can become a problem when the land is returned to row crop production.

Species respond differently to daily and longer terms of hydration and dehydration (Cavers 1994). Some species will have enhanced germination, some acquire an induced

dormancy, whereas other species are simply tolerant of dehydration during germination (Fenner 1985). Therefore, it is likely that weed seedbanks in the CRP land will vary depending on prevailing microclimate as well as the ability of individual species to withstand changes in soil moisture and temperatures over time.

Oxygen levels in the soil may play a central role in increasing seed mortality. Terpstra (1986) suggested that weed seed incorporated into the soil structural units will be exposed to low oxygen and higher moisture levels which are more conducive to seed dormancy than germination. Hendry et al. (1994) reported a highly significant correlation between the concentration of ortho-dihydroxyphenol in seeds and seed persistence in the soil. They concluded that ortho-dihydroxyphenol acts as a defense against herbivory and decomposition in cool temperate, relatively moist soils.

In row crop production systems, weed problems begin with seeds in the soil profile even though attempts are made to prevent the last weed in the field from going to seed (Wilson et al. 1985). Tillage employed in production systems has a major effect on weed seed placement and, therefore, weed seed longevity. Also, many agricultural weed species are very prolific seed producers and a high percentage of these seeds are viable, thus increasing the probabilities of survival in the seedbank (Holt 1988). Weed seedbanks in arable land may be quite large and are reported to range from 1,000 to 20,000 seeds m^{-2} (Kropac 1966) and as high as 496,000 seeds m^{-2} (Froud-Williams et al. 1983) depending on weed management systems employed. Giant foxtail (*Setaria faberi* L.) can produce over 10,000 seeds per plant (Screiber 1965) and red root pigweed (*Amarathus retroflexus* L.) over 100,000 seeds per plant (Stevens 1932). Thus, it is likely that cropped fields might support a

higher weed seedbank than adjacent CRP land where annual weed seed rain has been curtailed for a number of years.

The objective of this survey was to compare and characterize weed seedbanks in CRP and adjacent cultivated fields in anticipation of returning the land to row crop production.

MATERIALS AND METHODS

In the summers of 1997 and 1998, soil samples were taken from 63 of 99 Iowa counties to characterize the weed seedbanks in CRP and adjacent cultivated land. The CRP land sampled in this survey was enrolled as part of the 1985 United States Food Security Act and is considered to be highly erodible (HEL). By definition, this land has an erosion potential considered to be equal or greater than eight times the rate at which continued soil productivity can be maintained (USDA 1992). Samples were grouped according to the nine Iowa crop reporting districts (Figure 4.1). The CRP cover in these fields included orchardgrass (*Dactylis glomerata* L.), smooth bromegrass (*Bromus inermis* Leyss.), big bluestem (*Andropogon gerardii* Vitman), and switchgrass (*Panicum virgatum* L.), with some fields inter-seeded with alfalfa (*Medicago sativa* L.) and different species of sweet clovers (*Melilotus* spp). The adjacent cropped land was planted to either corn (*Zea mays* L.) or soybeans (*Glycine max* L.) and various tillage systems utilized.

The total land area under CRP in each district was not considered when the samples were taken. Therefore, an equal number of samples were taken from each district even though the southern one-third of Iowa has more CRP land than the central and northern tiers. Five sub-samples from each of two arbitrarily chosen CRP and two adjacent cultivated fields

per county were sampled for a total of twenty soil cores measuring 3.79-cm in diameter and 15-cm deep. While sampling, attempts were made to cover as great an area as possible in each field by walking in a zigzag fashion. Soil samples were transported to campus in cool containers and stored at -13 C until processed.

Samples were processed for seed recovery following the flotation method reported by Standifer (1980). Each sub-sample was placed in a beaker filled with 250 ml solution of sodium hexametaphosphate $[(NaPO_3)_6]$ at the rate of 56.5 g L^{-1}. Following 30 min of stirring at 200 rpm on an orbital shaker, samples were washed through a 250 μm openings sieve. The debris containing the weed seeds was collected on three layers of cheese cloth and dried at room temperature (± 25 C). Dry samples were processed individually and weed seeds identified and listed by species.

Preliminary analysis of variance (ANOVA) indicated no differences for square root transformed and non-transformed data. Therefore, non-transformed data were used in the final ANOVA using the SAS® system. The data were analyzed using a nested ANOVA model with counties nested within districts. Mean separations were done using the least significant difference (LSD) at $P \leq 0.05$. The raw data for each species were used to calculate Shannon's diversity index (H') (Stevenson et al. 1997) and thereafter subjected to AVOVA (Magurran 1988). Shannon's (H') is widely used for overall assessment of weed species diversity, and was calculated as follows:

$$H' = (N \log N - \sum n \log n)N^{-1} \quad [1]$$

where N is the total weed density per unit area and n is the weed density of each species present in the area. Shannon's E is a measure of species evenness or equal abundance and

was calculated as follows:

$$E = H' (\ln N)^{-1} \quad [2]$$

where H′ is Shannon's diversity index and E is weed evenness and *N* is the total weed density per unit area. A high degree of evenness, which occurs when species are equal or virtually equal in abundance, is conventionally equated with high diversity (Magurran 1988).

RESULTS AND DISCUSSION

District Characterization

The CRP land is not distributed uniformly in Iowa (Table 4.1). The NW district which borders South Dakota to the west and Minnesota to the north had the lowest land area under CRP, but ranked high in cropped area. The W district had the second lowest land area under CRP and the largest area of cultivated land. The S and SE districts had the largest land areas under CRP and ranked low in cultivated land area. The Iowa CRP land distribution reflected land productivity with less productive areas having the largest amount of CRP.

Weed Seedbank Characterization

Weed seeds for 18 species were recorded in CRP and adjacent cropped fields but in different proportions. These weeds included giant, green foxtail (*Setaria viridis* L.), and yellow foxtail (*Setaria glauca* L.), witchgrass (*Panicum capillare* L.), woolly cupgrass (*Eriochloa villosa* Kunth), common lambsquarters, pigweeds (*Amaranthus* spp.), Pennsylvania smartweed (*Polygonum pensylvanicum* L.), field pennycress (*Thlaspi arvense* L.), yellow sweetclover (*Melilotus officinalis* Lam), eastern black nightshade (*Solanum*

ptycanthum Dun.), velvetleaf (*Abutilon theophrasti* Medicus), wild buckwheat (*Polygonum convolvulus* L.), smooth groundcherry (*Physalis subglabrata* Mackenz. & Bush), yellow woodsorrel (*Oxalis stricta* L.), Venice mallow (*Hibiscus trionum* L.), wild mustard (*Brassica kaber* DC. L.C. Wheeler), and common ragweed (*Ambrosia artemisiifolia* L.). However, statistical analysis indicated only the seedbanks for foxtail species, common lambsquarters, pigweed species, and yellow sweetclover were significantly different between CRP and adjacent cropped fields (Table 4.2). Also, there were differences in weed seedbanks among the nine crop reporting districts, and, thus, means were separated by land usage within each district.

The weed seedbank tended to be larger in the cultivated land than in the adjacent CRP land. These differences could be associated with individual field management during and after CRP cover establishment. These results indicated that even though producers likely expended considerable effort to prevent weed seed production (Wilson et al 1985), cropped fields had a larger weed seedbank than adjacent CRP land.

Foxtail comparisons. Only the NW district of Iowa had a larger *Setaria* species seedbank in CRP than the adjacent cropped fields (Table 4.2). Cropped fields in this district had only 38% of the 4,915 foxtail seeds m^{-2} recorded in the CRP seedbank. The larger *Setaria* species seedbank in CRP land could be a reflection of continuous corn cropping system practiced prior to enrolling the land into CRP. In the northern (N) and W districts of Iowa, CRP had 58 and 48%, respectively of the foxtail seedbanks recorded in the adjacent cultivated fields. The cultivated fields in the E, S, SW, and southeast (SE) districts had an

average of 5,479, 3,326, 2,123, and 1,619 seed m^{-2}, respectively. The CRP fields in these districts had only 6, 18, 39, and 19% of the seedbank recorded in adjacent cultivated fields.

The higher foxtail seedbank in the cropped fields than in the adjacent CRP land could be associated with producer choices of weed management programs which likely had to accommodate soybeans in a rotation. Also, the lower seedbanks in the CRP fields likely reflected the successful establishment of the CRP cover, especially in the early years of the program. This resulted in very low annual *Setaria* species seed-rain in the CRP fields. Further, grass weed seeds generally are less persistent in the seedbank than broadleaf species (Lewis 1973). There was no difference in foxtail weed seedbank between CRP and adjacent cultivated fields in the NE and central (C) districts of the state.

Common Lambsquarters Comparisons. Common lambsquarters was one of the three broadleaf weeds with differences in seedbanks between cropped fields and adjacent CRP land (Table 4.2). Differences were observed in the N, C, and S districts; the average common lambsquarters seedbank in the N district was 4,128 seeds m^{-2} in CRP. This seedbank was more than five fold greater than that recorded in the adjacent cultivated fields.

The difference in common lambsquaters seedbank between the two land use systems was even more dramatic in the C district where CRP fields averaged only 252 seed m^{-2} compared to 3,801 seed m^{-2} in the adjacent cropped fields. Common lambsquarters seed longevity in the soil is relatively long. Lewis (1973) recorded 23% survival of common lambsquarters seeds following 20 yrs of seed burial. Thus, it is likely that the observed common lambsquarters seeds were part of the original seedbank before the land was enrolled

into CRP. The CRP land in the S district averaged 846 seed m^{-2} which was 47% of the seedbank recorded in the adjacent cropped fields. No differences in common lambsquarters seedbank between CRP and adjacent cropped fields were observed in the NW, NE, W, E, SW, and SE districts.

Pigweed Species Comparisons. Differences in pigweed seedbanks between CRP and adjacent cropped fields were observed in four of the nine crop reporting districts (Table 4.2). In the NE district, the CRP fields had 59% of the weed seeds recorded in the cropped fields (Table 4.2). Cropped fields in the C district had a very large pigweed seedbank which averaged 16,393 pigweed seeds m^{-2} compared to 4,172 seeds m^{-2} in CRP fields. A similar trend was observed in the S district where the cropped fields had an average of 23193 seeds m^{-2} but only 3,029 seed m^{-2} in CRP land. These results suggest that pigweed species were unable to establish if left on the soil surface as in CRP fields. Also, common waterhemp (*Amaranthus rudis* Sauer), the main pigweed species in the surveyed fields, tends to germinate later in the season in most cropping systems, and thus evades control by most chemical treatments (Buhler et al. 1997). This might likely contribute to the large seedbank in cultivated fields.

It is important to note that the C and S districts of the state had large common lambsquarters and *Amaranthus* species seedbanks in the cropped fields but not *Setaria* species. We suggest that weed management programs, crop rotations practiced, as well as common waterhemp biology could be a factor in the differences observed in the seedbanks of the two land use systems. Also, it was evident that some level of weed growth was supported

by patchy CRP cover. Patchy CRP cover enabled species to establish and produce seeds, albeit at a lower rate due to lack of incorporation into the soil as evidenced in the cropped fields. Similarly, the higher seedbank in cropped fields could be a reflection of tillage and accommodations for crop rotation employed by the producer.

Yellow sweetclover seedbank was larger in CRP fields than in adjacent cultivated fields for six out of nine districts in Iowa. This was expected since yellow sweetclover was seeded as part of the CRP cover.

Weed Species Population Variability

Even though the use of herbicides tends to reduce the weed seed population density, it does not eliminate weed species (Fryer and Chancellor 1970; Derksen et al. 1995). In this survey, only three (NW, E, and S) of the nine districts showed differences in the number of weed species comparing CRP and adjacent cropped fields (Table 4.2). No district had higher than three weed species in either of the land use systems. This is an indication that weed seedbank variability is mainly due to weed fecundity and not species variability.

Weed Diversity

Shannon's H′ was used because it is a composite index of diversity that incorporates both species richness and evenness (Magurran 1988). According to this measure, weed species diversity did not differ between CRP and cropped land usage system, nor were there any differences among districts (data not shown). It is important to remember that the Shannon's index of diversity is affected by weed density and the number of species in each

group. These conclusions are justified since the number of weed species was similar in CRP and cropped fields, and weed density differed in only a few fields.

The results of this survey identified a larger weed seedbank in continuously cropped fields compared to CRP land. Successful CRP cover establishment at the beginning of the program likely played a significant role in the reduction of weed seedbanks. However, the diversity of weed species was similar for CRP and adjacent cultivated land except for three districts. Farmers returning CRP land to row crop production are not likely to experience high levels of weed populations in the first year of production.

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Table 4.1. Total area in CRP and cultivated fields for the nine Iowa crop reporting districts.

District	Land use form	
	CRP	Cultivated
	ha	
Southwest	61815	720732
South	93783	514521
Southeast	94785	659507
West	22102	913495
Central	66721	907184
East	79739	897943
Northwest	2522	811484
North	52101	889726
Northeast	53324	823943

Table 4.2 Weed seedbanks for CRP and cropped land within each Iowa crop reporting district.

District	*Setaria* spp.		*Amaranthus* spp.		[a] YSC		C. lambsquarters		Species	
	Cropped	CRP	Cropped	CRP	Cropped	CRP	Cropped	CRP	Cropped	CRP
	Seeds m^{-2}								Number	
Northwest	1782 b	4915 a	9013 a	8924 a	15 a	74 a	608 a	1960 a	1.75 b	2.33 a
North	7127 a	4158 b	5509 a	4469 a	45 b	1366 a	4128 a	772 b	3.03 a	2.69 a
Northeast	3668 a	3148 a	20075 a	11760 b	0 b	460 a	3326 a	3846 a	2.73 a	2.80 a
West	1589 a	757 b	7840 a	10067 a	45 a	119 a	312 a	564 a	1.78 a	1.80 a
Central	2881 a	2302 a	16393 a	4172 b	15 b	416 a	3801 a	252 b	1.74 a	1.57 a
East	5479 a	312 b	4662 a	5850 a	30 b	371 a	624 a	1901 a	1.73 a	1.19 b
Southwest	2123 a	832 b	5672 a	1589 b	15 b	1574 a	639 a	579 a	1.66 a	1.46 a
South	3326 a	594 b	23193 a	3029 b	15 b	1886 a	1797 a	846 b	2.63 a	1.79 b
Southeast	1619 a	312 b	3772 a	4855 a	163 a	312 a	149 a	639 a	1.44 a	1.51 a
[b] $LSD_{(0.05)}$	2378		7741		920		2076		0.58	

[a] Yellow sweetclover

[b] Least significant difference for means within a column and weed species.

Means within a row and weed species followed by the same letter are not significantly different ($P \leq 0.05$) from each other.

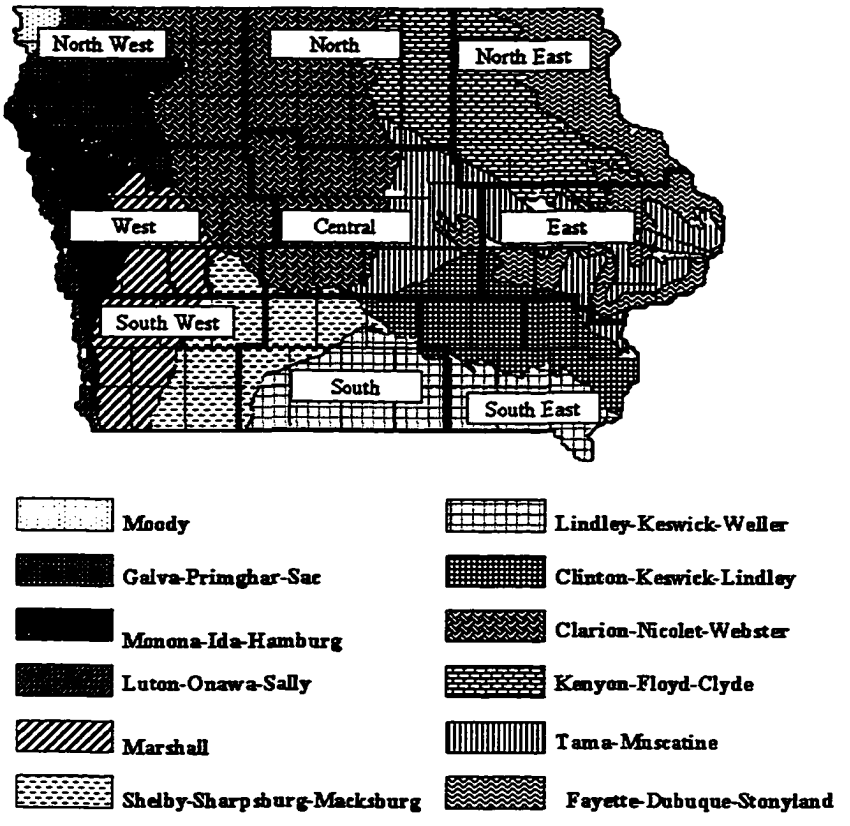

Figure 4.1 Iowa crop reporting districts and the twelve major soil series.

CHAPTER 5. EFFECT OF TILLAGE, CROPPING SYSTEMS, AND WEED MANAGEMENT ON SOIL FUNGAL POPULATION

A paper to be submitted for publication in the Weed Science Journal[1]

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Abstract: The effects of tillage, cropping systems, and weed management regimes on resident soil fungi were studied from 1994 to 1997. Results indicated that tillage and cropping systems did not influence the population density of the soil fungi observed in this study. A total of 44 fungi species were identified from the soil. Fungi Imperfecti comprised the largest group of fungi with 86% in 1994; 75% and 81% in 1995 and 1996, respectively, and 82% in 1997. Thirty eight species of fungi in 18 genera were Fungi Imperfecti, two species in three genera were Zygomycetes, and two species in one genus were Ascomycetes. *Trichoderma* and *Penicillium* species had the largest population densities with 23% each in 1994, 17 and 31% in 1995, 24 and 22% in 1996, and 26 and 25% in 1997, respectively. The no till system tested higher in phosphorus content compared to conventional tillage. This increase may be a direct result of reduced runoff under the no till system. It may also be related to phosphorus deposited on the surface by dead plant roots. Spring soil sampling

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resulted in higher fungal population densities compared to fall sampling. Some fungi responded to weed management regimes used in this study. Generally, the no herbicide treatment had higher fungal populations than band and broadcast treatments. Fungal populations may be affected more by environmental variables than tillage or cropping systems.

Nomenclature: *Trichoderma, Penicillium*

Key words: Fungi Imperfecti, Zygomycetes, Ascomycetes, genera, species.

INTRODUCTION

Soil is a complex of interrelated communities of soil organisms that influence, yet are in part determined by, the chemical and physical parameters of the soil. The cycling of nutrients in agricultural soils is, to varying degrees, dependent on the energy supply to and through the soil biota (Buchanan and King 1992). Although microorganisms make up only 1 to 8% of the soil organic matter (SOM), they influence crop production by acting as catalysts for bio-transformations (Roder et al. 1988). Through the processes of decomposition, immobilization, and mineralization, soil microorganisms control the flow of carbon, nitrogen, phosphorus, and sulphur through the terrestrial ecosystem (Sarathchandra et al. 1988).

Fungi are eukaryotic and many have filamentous septate mycelium (hyphae). Typically, a fungus hypha is 2-10 μm in diameter and greater than that of soil bacteria and actinomycetes (Killham 1994). Fungi are often the largest component of the microbial biomass in arable soils (Jenkinson and Ladd 1981; Killham 1994). Their distribution is related to the quality and quantity of organic material inputs and the method of soil tillage

employed (Schnurer et al. 1985; Beare 1993).

Changing the crop management system changes the soil microclimate and affects the soil biota (Paul and Clark 1989). In the absence of soil disturbance and reduced erosion due to permanent vegetation cover established for CRP, the level of SOM tends to stabilize rather than decrease as is the case with continuous plow tillage (Thomas 1986).

Changes in tillage practices alters plant residue placement in the soil profile (Bakermans and DeWitt 1970). Cropping systems that employ reduced- or no tillage (NT) management can improve soil aggregation, increase infiltration, and reverse the declines in SOM possibly through enhancement of soil biotic activity (Beare et al. 1997). Compared to conventional tillage (CT), NT management reduces soil disturbance and increases the surface placement of crop residues (Beare et al 1997). This in turn results in a higher fungal population which helps to conserve soil nutrients through fungal immobilization and slows SOM losses in NT systems due to higher fungal carbon assimilation efficiencies (Beare 1992; Hu et al. 1995; Holland and Coleman 1987).

Dawson et al. (1948) were among the first workers to study the effect of tillage on soil microflora. They reported that the top 2.5-cm of soil contained greater numbers of fungi, bacteria, and actinomycetes when the residues were left on the surface, whereas the 2.5- to 15-cm layer contained a greater number of microorganisms when the residues were plowed under. Beare et al. (1997) reported higher fungus population density in NT compared to CT, mainly due to a greater vertical stratification of the fungus population in NT than in CT where their populations are uniformly distributed through the profile (Doran 1980). Granatstein et al. (1987) reported that seasonal changes must be taken into account when

microbial biomass is compared.

Soil from a rotation of oat (*Avena sativa* L.) and red clover (*Trifolium pratense* L.) was found to have significantly greater fungal populations than soil from a system of continuous corn (*Zea mays* L.) (Fraser et al. 1988). Broder and Wagner (1988) working with corn, soybeans (*Glycine max* L.) and wheat (*Triticum aestivum* L.) residues in Missouri, reported variation of specific fungal genera attributable to environmental influences. Corn residue tended to harbor a higher fungal population densities than soybean and wheat residues. *Penicillium* species populations were reported to be higher during the growing season on residues of each specific crop cultivated. *Aspergillus* species had the highest populations in April and the lowest in September regardless of crop residue. *Trichoderma* species were isolated at high levels from the soil of corn plots during the summer months, but were a minimal portion of the fungal population isolated from corn residue.

Some herbicides are suspected to have stimulatory effects on some soil fungi. Atrazine [*6*-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine] has been reported to suppress the growth of *Fusarium oxysporum* (Rodriguez-Kabana and Curl 1970) and to stimulate the growth of *Trichoderma viride*, *Fusarium roseum*, *Geotrichum* sp. and *Penicillium* sp. (Gramlich et al. 1964). However, Martinez-Toledo et al. (1996) reported that simazine (6-chloro-*N,N'*-diethyl-1,3,5-triazine-2,4-diamine) did not influence fungal activity in the soil. Chahal et al. (1976) reported that *Penicillium* sp. and *Trichoderma* sp. are capable of degrading alachlor [*2*-chloro-*N*-(2,6-diethylphenyl)-*N*-(2-methoxymethyl) acetamide] in the soil. Krzysko-Lupicka and Orlik (1997) reported a predominance of *Mucor*, *Trichoderma*, and *Fusarium* species to the exclusion of *Penicillium* and *Cladosporium*

species when glyphosate [*N*-(phosphonomethyl)glycine] was used as a sole phosphorus source in the media. However, when glyphosate was used as the sole carbon source, only *Rhizopus*, *Trichoderma*, and *Mucor* species survived. These results agreed with those reported by Wardle and Parkinson (1992) that glyphosate could change the competitive saprophytic ability of soil fungi. Resident soil *Fusarium* species also had increased root colonization of glyphosate-treated plants (Rahe et al. 1990). Ruppel et al. (1988) reported that minimum, moderate, and intensive use of cyanazine [2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino]-2-methylpropanenitrile] had no detectable effect on *Fusarium* or *Trichoderma* species population densities in the soil. They further noted that changes in soil fungal population densities apparently were independent of crop rotation and weed densities under Colorado conditions. They suggested that changes in fungal population densities could be attributed to other environmental parameters.

The objective of this study was to investigate the effects of tillage, cropping systems, and weed management regimes on resident soil fungus populations over time in land previously under CRP in Iowa.

MATERIALS AND METHODS

The study begun in the summer 1994 and continued through summer 1997 at the Iowa State University (ISU) McNay Research and Demonstration Farm near Chariton, IA, on land previously in the conservation reserve program (CRP) for 8 yrs. The predominant soils at this location are Shelby-Adair silt loam (fine, montmorillonitic, mesic Typic Argiaquoll) with clay content ranging between 30 and 40%, and thus, low in permeability. Daily rainfall

data (maximum and minimum) were obtained from a nearby meteorology station. Microbial populations were evaluated in the spring and fall from 1994 through 1997. The CRP cover was a mixed seeding of big bluestem (*Andropogon gerardii* Vitman), smooth bromegrass (*Bromus inermis* Leyss), and yellow sweetclover (*Melilotus officinalis* Lam).

The study followed a split-plot design with four replications, and treatments were arranged in a randomized complete block. No-till and CT formed the main plots which measured 30.5- by 4.6-m. Two cropping systems (continuous corn and soybean/corn rotation) and the three weed management regimes (no-herbicide, banded, and broadcasted herbicides) formed the sub-plots. Conventionally tilled plots were moldboard plowed in 1994, and disc cultivated at the beginning of each following year just before planting. No-till plots were mowed in 1994 and the hay collected and removed. Following plant regrowth to 15-cm, plots were sprayed with glyphosate [*N*-(phosphonomethyl)glycine] at 1.69 kg a.i ha^{-1} to kill the CRP cover. Herbicide treatments for corn plots were a mixture of acetochlor [*2*-chloro-*N*-(ethoxymethyl)-*N*-(2-ethyl-6-methylphenyl)acetamide] and atrazine [*6*-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine] at 2.5 and 1.7 kg a.i. ha^{-1}, respectively. Soybean plots received a pre-emergence treatment of alachlor [*2*-chloro-*N*-(2,6-diethylphenyl)-*N*-(2-methoxymethyl) acetamide] at 2.7 kg a.i ha^{-1}. A 4.5-m boom equipped with six 8003EVS nozzles spaced 76-cm apart was mounted on an all-terrain vehicle (ATV) and used to apply a 38-cm band directly over the row on all banded treatment plots. Cultivation was done as appropriate given timing considerations. Also, hand weeding was done in all banded and broadcasted herbicide treatments as a post-emergence weed control measure.

Tillage treatments were done each spring, and main plots and sub-plots were maintained in the same location and received the same tillage, crop rotation, and weed management throughout the duration of the study. Plots were planted to locally adapted corn hybrid or soybean cultivar as appropriate at a depth of 5-cm using a six-row tractor mounted planter.

Soil Sampling and Plating

Soil sampling for fungi study was done during spring and fall from 1994 though 1997. Twenty sub-samples measuring 3.79-cm in diameter and 15-cm deep were taken in a zigzag fashion from each plot using a soil probe. In order to avoid soil contamination, the soil probe was dipped and rinsed with 95% methanol (CH_3OH) between plot sampling. Soil samples were immediately put in a cooler, transported to ISU campus and held frozen at -13 C until processed.

Fungus isolation was done using the soil dilution plate method as described by Parkinson (1994). The 20 sub-samples from each plot were pooled and thoroughly mixed before samples were taken for plating. Three 10 g sub-samples per plot were each placed in 90 ml autoclaved water blank, shaken and further diluted to 1×10^{-4}. Approximately 15 ml of cooled (45 C) peptone-dextrose agar amended with rose bengal and supplemented with streptomycin (Martin 1950) were added to each plate, and gently rotated to disperse the soil particles. One plate to which soil was not added was included during each isolation to check for possible media contamination during pouring. Fungi were enumerated following incubation at 25 C for 7 to 10 d. Colonies not penetrating the media after 7 d were gently

transferred onto peptone dextrose agar slants for additional growth time before identification. All isolates were subcultured on various media for identification. Fungi identification was done as per Ames (1961);Barnett and Hunter (1987); Raper and Fennell (1965); Raper and Thom (1949); and Watanabe (1994).

Analysis of transformed and non-transformed data produced similar results. Therefore, the non-transformed data were used in the analysis of variance (ANOVA) for each fungi species. A split-plot ANOVA model was used to analyze the data with PROC GLM of the SAS® system. The classes included tillage, cropping systems, and weed management regimes. Since no consistent results were obtained by analyzing individual species, fungi were grouped into their respective species for further analysis. The final ANOVA was done on the following groups: *Acremonium kiliense*, *Alternaria* spp., *Penicillium* spp., *Aspergillus* spp., *Cladosporium cladosporioides*, *Cylindrocarpon destructans*, *Cylindrocarpon olidum*, *Humicola* spp., *Fusarium* spp., *Epicoccum purpurascens*, *Gliocladium* spp., *Trichoderma* spp., *Myrothecium roridum*, *Paecilomyces inflatus*, *Paecilomyces lilacinus*, *Verticillium nubilum*, *Phoma* sp., all zygomycetes, all ascomycetes, unknown, and total fungal population.

Sorenson's similarity coefficient (SSC) was used to compare fungal populations between tillage, cropping systems, and weed management as follows:

$$SSC = \frac{2C}{A+B} x\,100 \qquad [1]$$

Where: A = total number of individuals in one group

B = total number of individuals in second group

C = the sum of the lower of the two abundances recorded for both groups.

Tests for soil organic matter (%), phosphorus (P), potassium (K), and pH were done according to the recommended chemical soil test procedures for the North Central Region (NCR-13 1998). The data were analyzed for each year using PROC GLM with a split-plot model using the SAS® system.

RESULTS AND DISCUSSION

Tillage and cropping system did not influence the resident fungal population density in this study. However, there were differences attributed to year, time of soil sampling, and weed management regimes; and no interactions were detected. A total of 44 different fungus species were identified from the soil (Table 5.1). The largest group was the Fungi Imperfecti with 38 species in 18 genera. There were three genera of Zygomycetes, and two were identified to species. The Ascomycetes were represented by two species in one genus. Two non-sporulating mycelial isolates were listed as an unidentified group. No Basidiomycetes were isolated.

Fungi Imperfecti comprised 86, 75, 81, and 82% of the total population in 1994, 1995, 1996, and 1997, respectively. *Trichoderma* and *Penicillium* species had the largest populations within the Fungi Imperfecti with 23% each in 1994, 17 and 31% in 1995, 24 and 22% in 1996, and 26 and 25% in 1997, respectively. *Fusarium* species were 10% of the total Fungi Imperfecti in 1994; 13% in 1995 and 1996; and 11% in 1997. Other groups within the Fungi Imperfecti, including *Aspergillus* spp., *Cladosporium cladosporioides*, *Cylindrocarpon* spp., *Epicoccum purpurascens*, and *Gliocladium* spp. had <10% each in any of the four

years. Of the Zygomycetes, *Mucor hiemalis* had the largest population with 89% in 1994; 99% in 1995; 92 and 73% in 1996 and 1997, respectively.

Soil Fertility Indicators

Neither crop rotation nor weed management regimes had any effect on observed SOM, phosphorus (P), potassium (K), and pH (data not shown). The SOM averaged 5% throughout the duration of the study, and K tested high to very high based on corn and soybean recommendations for Iowa (ISU extension 1996). The soil pH was between 6.7 and 7.0 throughout the duration of the study (Table 5.2). Phosphorus levels, however, were consistently higher in the NT than the CT. A number of researchers have reported reduced P loss through runoff and loss of sediment and nutrients from agricultural lands in NT compared to CT systems (Sharpley 1993; Chichester and Richardson 1992). Thus, the lower P levels in CT could have been the result of soil loss through surface erosion. Even though Thomas (1986) reported a decline in soil pH under NT conditions, our results indicated no tillage effect on soil pH. Gebhardt et al. (1985) reported that soil characteristics do not reach equilibrium until the management regimes have been established for 4 to 10 yrs.

Time of soil sampling affected the SOM only in 1996 (Table 5.3). In that year, spring sampling had an organic matter of 5.1 which dropped to 4.8 in the fall sampling. Also, soil P content was higher in the spring of 1995 and dropped in the fall sampling. The potassium tests showed no consistent results between spring and fall sampling. A higher potassium level was observed spring 1995 and 1997 and a lower level in spring 1996. Lower potassium levels in fall could be a result of summer crop uptake which is replenished by mineralization

to higher levels by the next spring. There were differences in soil pH between spring and fall sampling in 1995, 1996, and 1997 (Table 5.3). The soil pH was lower in spring of 1995 and 1996 and higher in 1997.

Effect of Soil Sampling Time on Fungus Populations

Fall soil sampling tended to result in a larger fungal count compared to spring counts (Table 5.4). Increased numbers for some fungal species probably was due to their known ecological functions in the soil. The population of *Aspergillus* species which are known to degrade atrazine in the soil (Kaufman and Kearney 1970) was high in fall and low in spring sampling only in 1996. However, weed management treatments which included atrazine had no influence on *Aspergillus* species populations (data not shown). Therefore, the observed increase in *Aspergillus* species populations in fall 1996 likely was related to other environmental factors and not atrazine use. *Trichoderma* and *Penicillium* species had the largest population in this study (Table 5.4). *Trichoderma* species may have cellulolytic activity, be parasitic on other fungi, produce toxins, or be considered to be an aggressive antagonist (Wacha and Tiffany 1979). These characteristics make *Trichoderma* species in the soil beneficial and possibly useful for biological control of potential plant pathogens (Wicklow 1972). Also, Rahe et al. (1990) reported an increase in *Fusarium* species population density with soil glyphosate treatment.

In this study, planting was late in 1995 due to wet conditions. Thus, glyphosate was applied on June 19 to kill all of the weeds prior to planting. This might have caused a larger *Trichoderma* species population in that spring. However, this response was not observed in

1996 and 1997 when glyphosate was applied on June 16 and May 16, respectively. Thus the higher *Trichoderma* species population in spring 1995 might have been related to other environmental factors and not the herbicide application. *Penicillium* species are classified as soil inhabitants because of their natural occurrence in the soil and completion of their life cycle in the soil (Widden and Parkinson 1973). The *Penicillium* species population was not different between sampling times in 1995, but was relatively high in fall 1996 and 1997. Chahal et al. (1976) reported that *Penicillium* sp. and *Trichoderma* species are capable of degrading alachlor. However, it is doubtful that the use of alachlor on soybeans in this study influenced *Penicillium* and *Trichoderma* species populations (data not shown). Because crop rotation did not influence fungal population in this study. The *Cylindrocarpon destructans* population was also high in fall 1996 and 1997 and the same pattern was exhibited by *Fusarium* species, some of which are known to be serious plant pathogens (Booth 1971). Wacha and Tiffany (1979) reported an increase in *Fusarium* species population related to NT practices and atrazine application. Our results indicated no tillage effect on *Fusarium* species population in the soil. Their results could have been related to higher atrazine rates which were double those used in this study.

Weed management regimes did not influence fungal populations in 1994 (Table 5.5). In 1995 and 1997, however, *Humicola* spp. population was high in the no herbicide treatment compared to band and broadcast treatments. In the third year of the study (1996), fungal population dynamics started to change. The population of *Acremonium kiliense* was high in the broadcast herbicide treatment in 1996 and 1997 (Table 5.5). The population of *Alternaria* spp. was higher in the no herbicide treatment only in 1996. *Cylindrocarpon destructans*

populations were also higher in the no herbicide treatment in 1996 and 1997. The population of Zygomycetes was higher in the no herbicide treatment only in 1997 with no difference between weed management regimes in the previous three years. The total fungal population in 1996 and 1997 was high in the no herbicide treatment compared to band and broadcast. Gramlich et al. (1964) reported the ability of *Penicillium* spp. to degrade atrazine. However, our results indicate that the population of *Penicillium* species was not affected by the herbicides in 1994 through 1996 (Table 5.5). In 1997, however, the no herbicide treatment had a higher *Penicillium* species population compared to band and broadcast. The lack of consistency in fungal population densities in response to herbicide used in this study suggests that other environmental factors might have played a role in the observed results.

The Sorensen's similarity coefficient (SSC) is based on the presense-absence relationship between the number of species common to two groups and the total number of species (Mueller-Dombois and Ellenberg 1974). The SSC for different treatment comparisons are presented in Table 5.6. The SSC are high for all comparisons because the fungal isolates were common to each pair, indicating that the treatments used in this study affected the fungi the same way. Pitty et al. (1987) and Wacha and Tiffany (1979) observed similar results. Pitty et al. (1987) concluded that both corn and soybeans provided the same type of nutrition and, thus, supported the same fungal populations. Our results suggest that resident soil fungi are not influenced by tillage or cropping systems. Also, there was no consistent results on the effects of herbicide application on resident soil fungal population. However, unidentified environmental factors might have been a key factor in the observed population differences.

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Table 5.1. Fungi isolated from the soil taken from the McNay research and Demonstration Farm, 1994-1997. Averaged across two tillage regimes, two cropping systems, and three weed management levels.

Fungus	Year			
	1994	1995	1996	1997
Fungi Imperfecti	—— Colonies g^{-1} oven dried soil ——			
Moniliales				
Acremonium kiliense Grutz	1822	3742	6880	9766
Alternaria spp.				
A. tenuissima (Kunze ex pers) Wilts	0	1169	1236	718
A. fumigatus Fres.	7483	798	4448	5250
A. ochraceus Wilhelm	6289	7877	6623	2338
Penicillium spp.				
P. diversum Rapper & Fannell	0	813	1415	4251
P. funiculosum Thom	5230	21740	18478	22599
P. islandicum Sopp	10991	6693	9358	16845
P. oxalicum Currie & Thom	4780	5429	2898	977
P. purpurogenium Stoll	0	1245	2119	9481
P. restrictum Gilman & Abbott	356	1055	2357	6924
P. velutinum Van Beyma	30194	22382	14200	19909
Aspergillus spp.				
A. fumigatus Fres.	3371	1050	3821	2829
A. clavatus	0	990	1193	5064
A. flavipes (Barn. &Sart.) Thom & church	0	259	760	1457
A. niger van Tieghem	6688	3676	6221	9370
Cladosporium cladosporioides (Fres.) De Vries	5912	2629	3154	8731
Cylindrocarpon destructans (Zins.) Scholten	41640	16148	15733	26985
Cylindrocarpon olidum (Wollenw) Wollenw.	72	1354	2541	3854
Humicola spp.				
H. fuscoatra Traaen	5787	911	8652	5511
H. grisen Traaen	8992	1134	2771	3865
Fusarium spp.				
F. stilboides Wollenw.	503	729	3803	6232
F. merismoides Corda	5528	6402	6523	7218

Table 5.1. (continued)

Fungus	Year			
	1994	1995	1996	1997
Fungi Imperfecti	colonies g^{-1} oven dried soil			
Fusarium concolor Reink.	3029	3610	1686	6802
F. oxysporum (Schl.) Emend. Snyder & Hansen	9787	10249	10854	8435
F. equiseti (Corda) Sacc.	3962	3171	6266	6702
Epicoccum purpurascens Ehrenb. Ex. Schlecht	0	1057	620	5515
Gliocladium spp.				
G. deliquescens Sopp	0	692	951	3836
G. roseum (Link) Thom	4780	18697	7133	6188
Trichoderma spp.				
T. hamatum (Bonorden) Bainier	17593	10242	21537	25659
T. harzianum Rifai	7479	2053	5946	15047
T. lignorum (Tode) Harz	12128	10958	8671	12672
T. aureoviride Rifai	4750	1165	1938	5562
T. pseudokoningii Rifai	11654	8374	15367	21647
T. köningii Oud.	0	0	1933	1366
Paecilomyces inflatus (Burnside) Carmichael	6876	4746	8533	5895
Paecilomyces lilacinus (Thom) Sampson	0	1390	1931	601
Verticillium nubilum Pethybridge	0	0	2638	6294
Sphaeropsidales				
Phoma sp.	852	4556	9316	8298
Zygomycetes				
Mucorales				
Rhizopus olisporus Saito	0	362	808	2420
Mortierella sp.	3355	110	1340	5122
Mucor hiemalis Wehmer	27339	40000	24073	20596
Ascomycetes				
Sphaeriales				
Chetomium spp.				
C. anguipilium Ames	3675	7985	9972	8294
C. virginicum Ames	1565	4884	5928	13579
Unidentified (Two groups)	1565	10181	10391	19616
Total	266027	252707	283016	390320

Table 5.2 Effect of tillage on soil organic matter (SOM), phosphorus (P), potassium (K), and soil pH averaged across two crop rotations and three weed management regimes.

Fertility	1994		1995		1996		1997	
indicator	NT[a]	CT	NT	CT	NT	CT	NT	CT
SOM (%)	5.2 a	5.0 a	5.4 a	5.0 a	5.2 a	4.7 a	5.1 a	4.6 a
P (ppm)	21 a	18 b	26 a	20 b	25 a	19 b	29 a	22 b
K (ppm)	232 a	184 a	239 a	198 a	262 a	215 a	241 a	198 a
pH	7.0 a	6.9 a	6.9 a	7.0 a	6.9 a	6.7 a	6.7 a	6.7 a

[a] NT = No till; CT = Conventional tillage

Means within a row and year followed by different letters are significantly different from each other according to LSD at $P \leq 0.05$

Table 5.3 Effect of soil sampling time on soil organic matter (SOM), phosphorus (P), potassium (K), and pH. Means averaged across two tillage, two crop rotations, and three weed management regimes.

Fertility indicator	1994	1995		1996		1997	
	Fall	Spring	Fall	Spring	Fall	Spring	Fall
SOM (%)	5.1	5.2 a	5.2 a	5.1 b	4.8 a	4.8 a	4.8 a
P (ppm)	19	25 a	22 b	23 a	22 a	27 a	25 a
K (ppm)	208	243 a	194 b	227 b	249 a	243 a	196 b
pH	7.0	6.9 b	7.0 a	6.9 b	7.0 a	7.0 a	6.5 b

Means within a row and year followed by different letters are significantly different from each other according to LSD at $P \leq 0.05$

Table 5.4. Effect of soil sampling time on fungi colony forming units (g^{-1} oven dried soil) at the McNay Res. farm, 1994-1997.

	1994	1995		1996		1997	
Fungus group	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Acremonium kiliense	1822	1813 b	5670 a	5452 b	8307 a	8645 a	10883 a
Alternaria spp.	13772	10006 a	9680 a	15078 a	9536 b	8702 a	7909 a
Penicillium spp.	51551	59760 a	58956 a	40833 b	60818 a	56127 b	105844 a
Aspergillus spp.	10059	5913 a	6039 a	8835 a	15155 b	17658 a	19781 a
Cladosporium cladosporioides	5912	2111 a	3147 a	3678 a	2629 a	10500 a	6963 a
Cylindrocarpon destructans	41640	11339 a	20956 a	10412 b	21055 a	12614 b	41357 a
Cylindrocarpon olidum	72	1680 a	1027 a	567 b	4514 a	2585 b	5123 a
Humicola spp.	14780	2048 a	2042 a	7226 b	15570 a	7095 b	11656 a
Fusarium spp.	22808	26290 a	22031 a	24493 b	33773 a	30446 b	40331 a
Epicoccum purpurascens	0	2114 a	0 b	0 b	1240 a	5974 a	5058 a
Gliocladium spp.	4780	27194 a	11586 b	6609 b	9559 a	10878 a	9171 a
Trichoderma spp.	53604	40180 a	25405 b	31231 b	79555 a	66795 b	97112 a
Myrothecium roridum	6876	3378 a	6113 b	11298 a	5769 b	6904 a	4885 a
Paecilomyces spp	ND[a]	ND	2780 a	289 b	8849 a	4559 a	9231 b
Verticillium nubilum	852	2047 b	7065 a	8802 a	9830 a	7343 a	9254 a
Phoma sp.	ND	ND	742 a	525 a	1090 a	2247 a	2594 a
Zygomycetes	34369	46277 a	49913 a	35793 a	34976 a	34313 a	33711 a
Ascomycetes	1565	2931 b	17430 a	7541 b	13241 a	18338 a	20895 a
Unidentified	14207	1548 a	1670 a	1522 b	3985 a	5021 a	5217 a
Total	278670	246628 a	252231 a	220235 b	339450 a	316747 b	446973 a

Means within a row and year followed by the same letter are not significantly different from each other according to LSD $P \leq 0.05$

[a] None detected.

Table 5.5. Effect of weed management regimes on fungal population at McNay Research and Demonstration Farm, 1994-1997.

	1994			1995		
	Management			Management		
Fungus group	No herbicide	Band	Broadcast	No herbicide	Band	Broadcast
Acremonium kiliense	1066 a	425 a	3977 a	3280 a	1957 a	5988 a
Alternaria spp	16425 a	12671 a	12218 a	11832 a	10040 a	7656 a
Penicillium spp.	58459 a	47581 a	48613 a	55041 a	64661 a	58419 a
Cylindrocarpon destructans	36330 a	42648 a	45942 a	21347 a	13969 a	13127 a
Humicola spp.	16153 a	13963 a	14223 a	2973 b	1309 a	1853 a
Epicoccum purpurascens	ND[a]	ND	ND	981 a	1528 a	661 a
Zygomycetes	849 a	1072 a	636 a	109 a	325 a	652 a
Unidentified	16735 a	13156 a	12739 a	1098 b	2641 a	1089 b
Total	296029 a	277071 a	262909 a	263936 a	250277 a	234076 a
	1996			1997		
Acremonium kiliense	6411 b	5006 b	9222 a	9308 b	6895 b	13093 a
Alternaria spp.	15675 a	11127 b	10119 b	9296 a	8421 a	7200 a
Penicillium spp.	52656 a	52790 a	47121 a	92897 a	80379 b	69681 b
Cylindrocarpon destructans	19335 a	14548 b	13316 b	34809 a	25295 b	20852 b
Humicola spp.	11708 a	11929 a	10632 a	11882 a	9390 b	6855 b
Epicoccum purpurascens	767 a	763 a	331 a	6752 a	5360 b	4434 b
Zygomycetes	910 a	649 a	865 a	3368 a	2019 b	1874 b
Unidentified	3699 a	2296 a	2266 a	6114 a	4851 a	4392 a
Total	303299 a	271660 b	264568 b	432327 a	359071 b	354182 b

Means within a row and year followed by the same letter are not significantly different from each other according to LSD P≤ 0.05
Population per g oven dry soil. [a] None detected.

Table 5.6. Similarity and frequency-similarity coefficients of fungal populations as affected by weed management regimes, tillage systems, and crop rotations at the McNay Research and Demonstration Farm, 1994-1997.

Comparison	Sorenson's similarity coefficient
No herbicide vs band	93.7
No herbicide vs broadcast	92.9
Band vs broadcast	99.5
No till vs conventional tillage	94.6
Corn/corn vs corn/soybeans	99.0

CHAPTER 6: GENERAL CONCLUSIONS

Cropping systems did not influence the number of weeds observed in the field nor did they affect the seedbanks. No tillage treatments harbored a higher weed population which was dominated by common waterhemp. Weed populations and seedbanks were affected by yearly weather variations. Fall soil sampling for seedbank characterization yielded a larger seedbank as a direct reflection of annual weed seed-rain. Weed management regimes had the greatest impact on weed population densities. No herbicide with cultivation as a sole measure of weed control resulted in a very large weed seedbank. The use of broadcast herbicide in no tillage environment should be recommended for land returning to row crop production. Conventional tillage plots had higher yields for corn and soybeans, however, tillage could reverse the achievements realized after 10 yrs of CRP by accelerating soil erosion. Crop establishment was better for soybeans compared to corn in the first year out of CRP. Thus, a rotation starting with soybeans should be recommended for the land coming out of CRP.

Tillage and cropping systems had no influence on resident soil fungal populations. Fungi Imperfecti dominated the soil fungal populations. No tillage plots had a higher phosphorus level possibly due to reduced surface soil erosion.

Weed seedbanks were higher in cultivated fields compared to CRP land. The nine Iowa crop reporting districts differed in weed seedbanks. The land under CRP had a larger seedbank compared to cropped fields. The seedbank in all of the nine crop reporting districts was dominated by broadleaf weeds and very low in grasses.

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IMAGE EVALUATION
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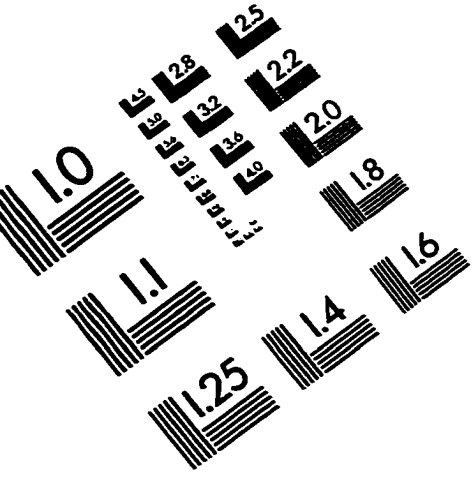

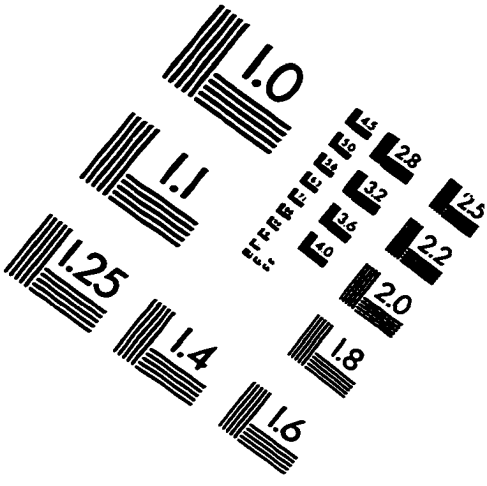

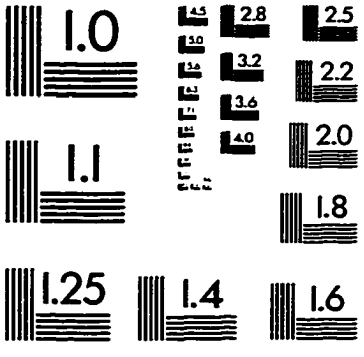

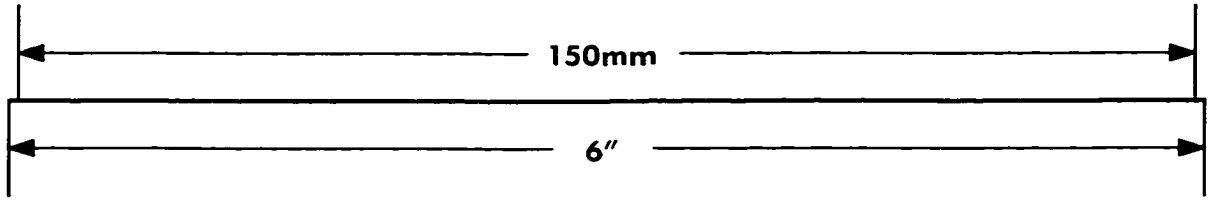

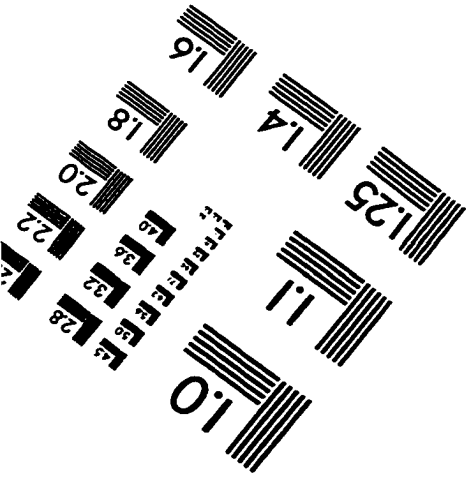

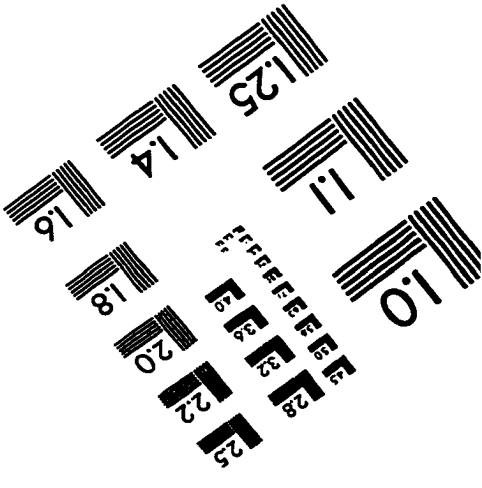

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